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Analysis of How Post-harvest Processing Technologies for Controlling *Vibrio vulnificus* Can Be Implemented

Contract No. GS-10F-0097L, Task Order 8

Final Report

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- Pappas Restaurants, Texas
- Prestige Oysters, Texas
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- Steve Otwell, University of Florida
- Webb's Seafood, Florida
- Wilson's Oysters, Louisiana

DISCLAIMER

The results presented in this report are based on data and information provided by companies that currently manufacture PHP equipment or conduct PHP activities for raw oysters. The use or mention of any trade names, commercial products, or company names in this report does not constitute an endorsement or recommendation for use by RTI International. Furthermore, RTI has no opinion on whether PHP of oysters should be required, nor, if processing was required, on which products should be included in a requirement.

Executive Summary

No longer satisfied with the progress being made to reduce illnesses associated with *Vibrio vulnificus*, in October 2009, the Food and Drug Administration (FDA) announced its intent to reformulate its policy regarding post-harvest processing (PHP) of Gulf oysters harvested during the warm-weather months that are intended for raw half-shell consumption. Under contract with FDA, RTI International conducted a study to analyze the feasibility and economic impacts of requiring PHP of Gulf state (Alabama, Florida, Louisiana, Mississippi, and Texas) oysters harvested in the summer (April through October) and intended for raw half-shell consumption. Applicable PHP methods are those that have been determined to reduce *Vibrio vulnificus* to nondetectable levels (<30 MPN/gram), including cool pasteurization, cryogenic individual quick freezing (IQF) with extended frozen storage, high hydrostatic pressure (HHP) processing, and low-dose gamma irradiation.

The analysis of the effects of PHP requirements was subject to limitations resulting from two major events affecting the oyster industry:

- the Deepwater Horizon oil spill in April 2010, which resulted in numerous harvest area closures and significant death of oysters from fresh water diversions that were used to prevent oil from reaching shorelines and
- imposition of time-temperature requirements in Gulf states in May 2010, which for some states are as restrictive as a 1-hour limit from harvest to refrigeration in the summer months.

Both of these events have caused and will cause substantial reductions in oyster harvests for several years into the future.

For the purposes of the analysis, we relied on data for 2008 as a representative baseline to allow estimation of quantitative impacts separately from the impacts of the oil spill and time-temperature requirements. Because oyster harvest volumes will be substantially reduced because of these events, fewer oysters would require PHP based on more current data. When the oyster industry recovers from the effects of the oil spill and possibly more harvesters are able to comply with time-temperature requirements, harvest levels may return to more normal levels. It should be noted that using a PHP method allows processors to sell oysters harvested outside of the time-temperature requirements for raw half-shell consumption and, thus, may help offset reductions in harvest that occur as a result of harvesters being unable to comply with the time-temperature requirements.

The key results of the analysis are as follows:

- The feasibility of the post-harvest processes for summer-harvested Gulf oysters intended for the raw half-shell market are as follows:
  - **Cool pasteurization**—feasible and currently in use in one Gulf operation (with one more operation planned)
  - **HHP processing**—feasible and currently in use in three Gulf operations
  - **Low-dose gamma irradiation**—feasible for operations within a reasonable transportation distance from an irradiation facility in Mulberry, Florida, depending on whether labeling issues can be resolved and consumers accept the product in the marketplace
  - **IQF with extended storage**—not feasible for summer-harvested Gulf oysters given substantial quality reduction (eight Gulf operations currently use IQF for Gulf oysters harvested during cool-weather months)
  - **High salinity treatment**, which is sometimes referred to as salt-water relaying—currently not feasible given substantial technical challenges and permitting issues

- On a per-oyster basis, costs of PHP using cool pasteurization or HHP processing range from 4 to 7 cents for raw half-shell oysters and −3 to 0 cents for shucked oysters, including both annualized capital and annual operating costs. Cost savings associated with shucked oysters are obtained in some cases because of the increased yields and reduced shucking labor associated with processed oysters. These estimates do not include transportation costs if needed to obtain PHP services from a central facility.
- Average monthly PHP capacity currently available in the Gulf, assuming all operations with cool pasteurization or HHP processing equipment operate 4,800 hours per year, is 167 million oysters, which is 27% of the estimated average monthly Gulf summer harvest and 66% of the estimated average monthly half-shell Gulf summer harvest shipped interstate.
- In addition to using a post-harvest process, other potential responses to requirements for PHP of summer-harvested Gulf oysters intended for the half-shell market are as follows:
  - marketing of oysters within the state of harvest if the states will allow intrastate shipments of unprocessed oysters and
  - closure of harvest beds by state agencies.

  Switching from half-shell to shucked-only production is not a feasible alternative response for oyster operations because of the substantially lower yields, resulting in negative returns, associated with shucking summer-harvested oysters due to spawning.
- To install additional PHP equipment to augment existing PHP capacity would require at least 2 years for Gulf oyster operations for activities such as the following: developing plans for expanding the plant or altering the plant layout; obtaining building permits; securing financing for purchasing equipment; constructing the expanded facility; modifying electrical, natural gas, and water hookups; purchasing and installing equipment; validating and verifying the process; training workers; updating the operation's Hazard Analysis and Critical Control Point (HACCP) plan to address PHP; updating record-keeping systems; and updating product labeling and notifying buyers.
- An estimated 6 to 11 oyster processing operations (4 to 8% of Gulf shellstock oyster operations representing up to 60% of Gulf oyster volumes) have sufficient oyster

processing volumes to warrant installation of PHP equipment within the plant (beyond those that are already operating cool pasteurization and HHP with sufficient capacity to process all their oysters). However, nearly all of these operations would have negative profits as a result of PHP costs if oyster prices do not change in response to PHP requirements.

- Establishment of central PHP facilities for summer-harvested Gulf oysters will likely be needed to allow for PHP by the remaining establishments. The optimal locations for establishing central PHP facilities given the location of Gulf oyster processing operations and assuming a maximum monthly processing volume of up to 7 million oysters per central PHP facility, based on a geographic information systems (GIS) analysis are as follows:
  - Apalachicola, Florida 32329
  - Bayou La Batre, Alabama 36509
  - New Orleans, Louisiana 70142 or 70195
  - Houma, Louisiana 70361
  - San Antonio, Texas 78279
  - St. Augustine, Florida 32086 (if oyster processors do not use the irradiation facility in Florida)
- To establish a central PHP facility in the Gulf, which would likely need to be operated by a local or state agency, at least 3 years would be required to allow for activities such as the following: determining the legal and operating structure of the operation; securing financing for the operation; identifying a specific property with the intent of modifying an existing facility or building a new facility; developing plans for expanding and altering an existing facility or building a new facility; obtaining necessary permits; constructing the facility and hooking up electrical, natural gas, and water supplies; purchasing and installing equipment; validating and verifying the process; hiring and training workers; preparing a HACCP plan; conducting test operations; and conducting outreach and education to the industry to develop the clientele.
- Even with the establishment of central PHP facilities, an estimated 20 oyster processing establishments (14% of Gulf shellstock oyster operations representing 6% of Gulf oyster volumes) are predicted to shut down during the summer months because the costs of PHP relative to sales revenue would exceed the estimated profit ratios

of the establishments if the price of half-shell oysters does not change in response to PHP requirements. However, some of the operations may not typically operate in the summer under normal conditions.

- The total initial capital equipment purchase and installation costs associated with PHP for Gulf oysters is estimated to be $6 million to $32 million, depending on which process is installed, excluding the costs of land purchases and new building construction for central processing facilities. On an annual basis, the total industry cost associated with PHP for Gulf oysters harvested during summer months is estimated to be approximately $8 million. These estimates assume that operations with sufficient product volumes to install PHP equipment will install the equipment and apply the PHP process to all half-shell and shucked oysters during the summer months and that operations with insufficient product volumes to install PHP equipment will use a central PHP facility at a cost of 4.9 to 5.4 cents per oyster (not including transportation costs) for only half-shell oysters shipped interstate during the summer months.
- Likely consumer responses to post-harvest processed oysters are as follows:
  - Based on a 2010 sensory study conducted by the University of Florida, consumers of raw oysters were willing to accept the four types of post-harvest processed oysters included in the study (HHP, irradiated, IQF, and a simulated version of cool pasteurization) but preferred traditional oysters to post-harvest processed oysters at 7 days post-harvest; however, panelists were less able to discern differences between PHP and traditional oysters at 14 days post-harvest (Otwell et al., 2010).
  - Based on the other sensory studies that we reviewed, consumers of raw oysters and individuals on trained sensory panels could not detect differences between traditional and post-harvest processed oysters, with the exception of previously frozen oysters.
  - Based on the other consumer surveys that we reviewed, most consumers are not willing to buy post-harvest processed oysters, and of those who are, they are willing to pay about the same amount as they would for traditional oysters. Information was not available on reasons consumers are not willing to buy post-harvest processed oysters.

  - Findings from nine interviews with restaurant managers and owners suggest that consumer response to treated Gulf oysters will vary and will depend on factors such as the type of post-harvest process used and consumer characteristics (e.g., the frequency with which raw oysters are consumed).

- PHP requirements are predicted to result in the following ranges of market effects, assuming consumers are indifferent between processed and traditional oysters:
  - 5.6 to 11.5% increase in the price of raw half-shell Gulf oysters sold in the summer
  - 3.8% decrease in the volume of raw half-shell Gulf oysters sold in the summer
  - 3.7% decrease to 1.8% increase in the price of shucked Gulf oysters sold in the summer
  - 3.0 to 5.0% increase in the volume of shucked Gulf oysters sold in the summer
  - 0.5 to 1.8% decrease in the price of Gulf shellstock oysters sold in the summer
  - 0.3 to 1.1% decrease in the volume of Gulf shellstock oysters purchased in the summer
  - 1.7 to 3.8% increase in half-shell oysters and 0.8% decrease to 1.6% increase in shucked oysters produced in other regions of the country to compensate for changes in the Gulf region

In some cases, the predicted percentage increases in prices for post-harvest processed oysters are less than those that would allow all oyster processors to continue to operate profitably following implementation of PHP requirements.

In summary, to feasibly and cost-effectively impose requirements for PHP of summer-harvested Gulf oysters intended for raw half-shell consumption would require the following:

- Establishment of 5 or 6 central PHP facilities for use by the smallest establishments unless smaller establishments are assumed to close operations in the summer in response to the requirements. Initial costs of PHP equipment for these facilities are estimated at $2 million to $11 million. Additional costs would be incurred for purchasing land and building the facilities.
- Technical and financial assistance to an estimated 6 to 11 establishments to install their own PHP equipment.

Initial costs of installing PHP equipment in these facilities are estimated at $3 million to $22 million including the costs of expanding the existing plants but not purchasing additional land.

- A minimum of 3 years for establishing central PHP facilities and 2 years for installing PHP equipment within existing establishments.

Even with these allowances, requirements for PHP for all summer-harvested Gulf oysters intended for the half-shell market will cause substantial challenges for the Gulf oyster industry and reductions in Gulf oyster production in the short run. The Gulf oyster industry is currently adjusting to the effects of the Gulf oil spill and new time-temperature requirements for Gulf-harvested oysters and, therefore, may be less able to respond effectively to PHP requirements. However, using a PHP method would allow oysters that are harvested outside of new time-temperature requirements to be used for raw half-shell consumption and, therefore, may help alleviate challenges associated with the time-temperature requirements.

1 Introduction

The purpose of this study is to determine the feasibility and economic impacts of requiring PHP of all summer-harvested (April through October) Gulf oysters intended for the raw half-shell market.

In spring 2010, the Food and Drug Administration (FDA) contracted with RTI International to conduct a study to analyze the feasibility and economic impacts of requiring post-harvest processing (PHP) of Gulf state (Alabama, Florida, Louisiana, Mississippi, and Texas) oysters harvested in the summer (April through October) and intended for raw half-shell consumption. Applicable PHP methods are those that have been determined to reduce *Vibrio vulnificus* to nondetectable levels, including cool pasteurization, cryogenic individual quick freezing (IQF) with extended storage, high hydrostatic pressure (HHP) processing, and low-dose gamma irradiation. Requirements would specifically apply to interstate shipments of oysters harvested from the Gulf, although oysters could be post-harvest processed before or after crossing state lines. Individual Gulf states would decide whether intrastate shipments would also be subject to the requirements if implemented.

The Deepwater Horizon oil spill in April 2010 and the imposition of new time-temperature requirements for Gulf-harvested oysters in May 2010 complicated the analysis because of the ongoing substantial reduction in Gulf oyster harvests.

The analysis of the effects of PHP requirements was subject to limitations resulting from two major events affecting the oyster industry:

- the Deepwater Horizon oil spill in April 2010, which resulted in numerous harvest area closures and significant death of oysters from fresh water diversions that were used to prevent oil from reaching shorelines and
- imposition of time-temperature requirements in Gulf states in May 2010, which for some states are as restrictive as a 1-hour limit from harvest to refrigeration in the summer months.

Both of these events have caused and will cause substantial reductions in oyster harvests for several years into the future. Thus, establishing a representative baseline for oyster volumes and prices for conducting the analysis is difficult. Based on data availability, we conducted the analyses using baseline data for 2008 to allow estimation of quantitative impacts separately from the impacts of the oil spill and time-temperature requirements. Because harvest volumes will be substantially reduced as a result of these events, fewer oysters would require PHP based on more current data. However, using a PHP method would allow oysters that are harvested outside of new time-temperature requirements to be used for raw half-shell consumption and, therefore, may help alleviate challenges associated with the time-temperature requirements. When the oyster industry recovers and possibly more harvesters are able to comply with time-temperature requirements or find buyers with PHP capability, harvest levels will likely return to more normal levels.

1.1 BACKGROUND AND OBJECTIVES

Vibrio vulnificus is a naturally occurring bacterium found in seawater along the Gulf, Atlantic, and Pacific Coasts, although it is most prevalent in the warm waters of the Gulf of Mexico. *Vibrio vulnificus* can be transmitted to humans through the consumption of raw shellfish harvested from waters containing the organism. Oysters from the Gulf of Mexico have been recognized as the primary species of molluscan shellfish associated with *Vibrio vulnificus* illnesses in consumers. *Vibrio vulnificus* does not normally affect healthy individuals, but persons who are immunocompromised, especially those with chronic liver disease, are at greater risk for contracting *Vibrio vulnificus* from oyster consumption. In immunocompromised individuals, there is a risk for the organism to invade the bloodstream, resulting in potentially fatal septicemia. Although the annual number of reported *Vibrio vulnificus* illnesses associated with oyster consumption is low, generally in the range of 30 to 35, the incidence of death among those individuals who contract the disease is high, at approximately 50%.

Over the past decade, the federal government has devoted significant resources to reducing foodborne illness from all sources. However, Centers for Disease Control and Prevention

(CDC) data show that the incidence of *Vibrio vulnificus* illness from raw oyster consumption has essentially remained constant (CDC, 2011). The epidemiological record indicates an annual occurrence of multiple *Vibrio vulnificus* infections associated with consuming raw oysters from the Gulf of Mexico during April through October. Controls such as implementation of a 5-hour time limit from harvest to refrigeration imposed by Gulf states in 2008 to control *Vibrio parahaemolyticus* and educational efforts for consumers and health care providers have not been effective in reducing the risk of *Vibrio vulnificus* illness. Furthermore, FDA does not believe that measures aimed at reducing the hazard, but that fall well short of eliminating it, are sufficient.

The safety of molluscan shellfish for raw consumption is primarily controlled in accordance with the sanitary measures of the National Shellfish Sanitation Program (NSSP). The NSSP was initially developed to protect consumers against enteric pathogens associated with fecal contamination of the waters from which they are harvested, in particular human fecal waste. Because *Vibrio vulnificus* is naturally occurring and is not associated with fecal pollution, the existing NSSP controls did not offer a strategy for controlling *Vibrio vulnificus*. In an effort to better control *Vibrio vulnificus* in oysters, in 2001 the Interstate Shellfish Sanitation Conference (ISSC), in conjunction with FDA, developed a *Vibrio vulnificus* Control Plan for inclusion in the NSSP. Because voluntary efforts to substantially reduce *Vibrio vulnificus* illnesses in the initial phase of the plan were not successful, the Control Plan requires states that have two or more etiologically confirmed shellfish-borne *Vibrio vulnificus* septicemia illnesses to develop and implement controls necessary to reduce the incidence of illnesses associated with raw oyster consumption by 60%, as measured by illnesses reported collectively by California, Florida, Texas, and Louisiana. Current efforts by states to reduce the incidence of *Vibrio vulnificus* illness are primarily focused on promulgating mandatory time from harvest to refrigeration requirements and limited additional use of PHP technologies for reducing *Vibrio vulnificus* levels to nondetectable (<30 MPN/gram). Although it is too early to assess fully the effect of the more stringent time-temperature requirements implemented by the Gulf states in May 2010, illness data for 2010 reported to date do not indicate a

reduction in illnesses even with decreased harvest volumes associated with the Gulf oil spill (ISSC, 2011).

No longer satisfied with the progress being made under the NSSP plan, in October 2009, FDA announced its intent to reformulate its policy on controlling *Vibrio vulnificus* in raw oysters as it relates to the federal *Seafood HACCP Regulation*, 21 CFR Parts 123 and 1240, specifically regarding PHP of Gulf oysters harvested during the warm-weather months that are intended for raw consumption. Industry, academia, and government, with support from the ISSC, have developed PHP technologies that can largely eliminate this hazard while preserving the organoleptic qualities of raw oysters. These technologies include IQF with frozen storage, HHP, mild heat, and low-dose gamma irradiation.

Since making the announcement, FDA has heard from Gulf Coast oyster harvesters, state officials, and elected representatives from across the region about the feasibility of implementing PHP or other equivalent controls by the summer of 2011. It became clear to FDA from these discussions that there is a need to further examine both the process and timing for large and small oyster harvesters to gain access to processing facilities or equivalent controls in order to address this important public health goal. Therefore, in a second October statement, FDA announced that before proceeding it would conduct an independent study to assess how PHP or other equivalent controls can be feasibly implemented in the Gulf Coast in the fastest, safest, and most economical way.

1.2 OBJECTIVES

This task order has two primary objectives:

- **Objective 1:** For the Gulf states (Texas, Florida, Alabama, Mississippi, and Louisiana), assess how PHP or other equivalent controls can be feasibly implemented in the fastest and most economical manner. The assessment will cover PHP implementation during the period of April through October and include, but not necessarily be limited to, the establishment of PHP cooperatives, use of existing PHP facilities by outside harvesters and processors, and PHP phase-in to address problems faced by smaller oyster processors. Consideration will also be given to the percentage of oysters that will shift from the raw consumption market

to the shucked oyster market, as well as potential harvest closures that may result from PHP capacity shortfalls.

- **Objective 2:** In addition to assessing mechanisms for implementing PHP in the Gulf, conduct a cost analysis associated with Gulf-wide implementation of PHP during the period of April through October.

It is important to keep in mind that PHP requirements will apply only to oysters shipped interstate. However, some states may choose to also require PHP for oysters sold within the state (i.e., intrastate shipments). Some proportion of oysters is currently only shipped intrastate, and this proportion may change depending on how each state chooses to implement the requirements.

1.3 ORGANIZATION OF THIS REPORT

The remainder of this report is organized as follows. Section 2 provides a profile of the Gulf oyster industry in relation to the U.S. oyster industry and oyster imports and exports. Section 3 provides descriptions of the available and potential PHP methods, requirements for validation and verification of processes, and consumer response to post-harvest processed oysters. Section 4 presents assumptions used in the analysis, the costs of implementing and operating PHP methods, and an analysis of the feasibility of PHP for all summer-harvested Gulf oysters. Finally, Section 5 provides the results of the business closure and market assessments if PHP of all summer-harvested Gulf oysters intended for the raw half-shell market were required.

In the appendix, we provide copies of interview guides used throughout the study, including a brief questionnaire for restaurants that serve raw Gulf oysters. Because limited time and resources prevented obtaining Office of Management and Budget (OMB) clearance for conducting formal surveys, data collection was limited to no more than nine respondents for each specific list of discussion topics.

2 Overview of the Gulf Oyster Industry in Relation to the U.S. and World Markets

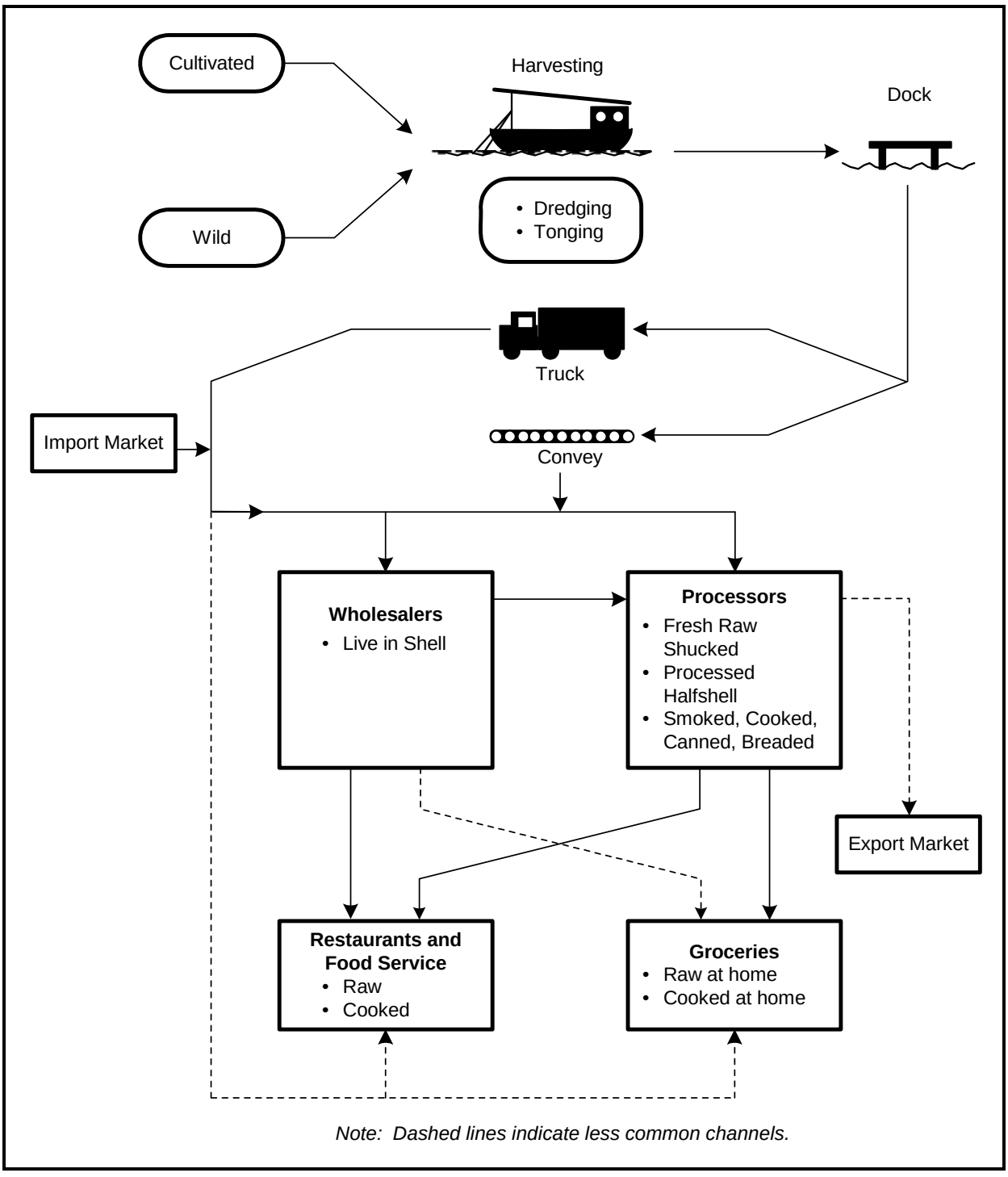
This industry profile is based on historical data. Estimates of the effects of the Deepwater Horizon oil spill and time-temperature requirements are currently unknown.

The purpose of the industry profile is to identify the stakeholders in the industry that would potentially be affected by a post-harvest treatment requirement, describe the factors affecting supply and demand for oysters, and provide data on the industry to be used in the feasibility and economic analysis. In this profile, we emphasize the processing and wholesale sector because the initial burden of installing and operating treatment equipment would fall most directly on existing shellstock processors. However, harvesters will also be affected, so we also describe them briefly.

Figure 2-1 provides a simplified overview of the oyster industry from harvesting to final consumption. The actual movement of oysters from harvest to consumers may differ from that shown in Figure 2-1 in subtle or significant ways, especially from region to region, depending on laws and customs.

Essentially there are three main "sectors" in the oyster industry: harvesters, processors, and retailers. Harvesting operations, which can vary anywhere from purely "wild" harvesting to highly managed cultivating operations, bring mature oysters from waters to wholesalers/processors. Some harvesters deliver oysters directly to restaurants or other retail outlets, but it is more common for harvesters to sell their oysters either to wholesalers or processors. Wholesalers may repack shellstock into sacks, boxes, or bushels and sell them to other wholesalers or to processors. Wholesalers may also sell shellstock directly to restaurants or retailers.

Figure 2-1. Oyster Harvesting, Processing, and Distribution
Post-harvest treatment activities will occur at oyster wholesaling and processing plants.



Sources: Muth, M.K., D.W. Anderson, S.A. Karns, B.C. Murray, and J.L. Domanico. 2000. "Economic Impacts of Requiring Post-Harvest Treatment of Oysters." Prepared for the Interstate Shellfish Sanitation Conference, Columbia, SC. Research Triangle Park, NC: RTI International.

Anderson, D.W., R.C. Lindrooth, B.C. Murray, and J.L. Teague. 1996. "Cost of Restrictions on Gulf Oyster Harvesting for Control of *Vibrio vulnificus*-Caused Disease." Research Triangle Park, NC: Research Triangle Institute.

Wholesalers and processors are generally located near the water's edge with loading docks for conveying oysters from the boats into refrigerated trucks. All shellfish shippers, also known as dealers, must be certified with the NSSP in order to receive or ship any shellfish products in interstate commerce (FDA, 2007).

The remainder of this section is organized as follows. Section 2.1 discusses the harvesting sector of the industry, which could be indirectly affected by post-harvest treatment requirements as the derived demand for oysters changes. We also discuss each of the Gulf states in this section. Section 2.2 describes the processing sector of the industry, which would be most directly affected by post-harvest treatment requirements. Section 2.3 describes interregional and international trade for oysters because trade flows may be affected by treatment requirements.

2.1 HARVESTING

This section provides basic information about oyster harvesting in the United States and presents harvest data used in our economic analysis. PHP requirements would be expected to most immediately and directly affect oyster processing companies as they work to comply with the requirements. Oyster harvesters will also be affected, however, as the "derived demand" for shellstock changes. Processors that purchase their oysters must install treatment equipment, determine another method of obtaining treatment services, or close during the summer. Thus, the market for shellstock oysters purchased from harvesters may be reduced depending on whether oyster processors are able to adapt to the requirements.

Oyster harvesters have already been affected by the time-temperature requirements that were implemented in May 2010 because harvesters without coolers or with insufficient cooler capacity on their boats have either incurred substantial costs to install coolers or are unable to harvest oysters when time-temperature requirements are in place. Oyster harvesters that lack the resources to install coolers on their boats to comply with the time-temperature requirements may be able to harvest and sell oysters that will undergo PHP or be shucked.

Shellstock oysters can be either natural, managed natural, or cultivated. Natural oysters grow and reproduce without human intervention in naturally occurring oyster beds. Managed natural oyster beds are tended by harvesters, even in the off season, mainly by raking the beds periodically to reduce clustering. In some regions of the United States, particularly the Northwest, nearly all shellstock oysters are produced on cultivated beds. In the Northeast, a significant portion of shellstock oysters are produced on cultivated beds, but some are harvested from wild reefs. In the Gulf, the majority of shellstock oysters are harvested from wild reefs.

Oyster harvesters can harvest from both private and public grounds. Anyone with a state-issued shellfish license can harvest oysters from public grounds during the open season. To harvest from private grounds, oyster harvesters pay the state a set amount of money, usually per acre, to lease a specific area in which to grow and harvest oysters. In Louisiana, the private lease fee is $2 per acre (Bagala, 2010). Many private leases have been held by the same families for generations. On private leases, oystermen spread shells, concrete, or crushed limestone for larvae. They also transfer young oysters, or spat, from other areas to seed their leases. Generally, the reef can be harvested after 2 years (Felsher, 2009).

To harvest oysters, oystermen use tongs or rakes, depending on individual state laws. Rakes are metal devices that lift the oysters from the sea bottom and deposit them into wire baskets. This is done from 40- to 60-foot boats operated by a boat captain and two to four crew members (Felsher, 2009). Harvesters that use tongs have smaller boats, generally about 20 feet long (City of Apalachicola, 2006). Oysters are then placed in sacks and brought to a dock.

Any harvester-level regional effects of post-harvest treatment requirements will depend on many factors, including the importance of the oyster industry in the region. Table 2-1 presents harvest and price data by state in 2008 in the Atlantic, Gulf, Northeast, and Pacific regions. Harvests are reported as meat-weight equivalents for which the amount of shellstock from the bushel, sack, or tub has been converted to its approximate meat-weight yield. Meat yield conversions vary by place and month and are determined by the individual state offices that report harvest data to the National Marine Fisheries

Table 2-1. Nationwide Oyster Harvests by State, 2008
Oyster harvests are reported for 21 states in four regions of the country.

Region	State	Meat-Weight Pounds	Value ($)	Harvest Price ($/meat-weight lb)
Atlantic	DE	67,312	$410,099	$6.09
	FL East Coast	47,611	$168,291	$3.53
	GA	12,840	$54,011	$4.21
	MD	249,441	$2,277,040	$9.13
	NC	466,177	$2,039,166	$4.37
	SC	324,491	$1,739,216	$5.36
	VA	381,835	$2,959,570	$7.75
Atlantic Total		1,421,944	$9,014,992	$6.34
Gulf	AL	72,776	$243,414	$3.34
	FL West Coast	2,501,475	$5,472,823	$2.19
	LA	12,787,438	$38,838,822	$3.04
	MS	2,610,349	$6,869,160	$2.63
	TX	2,679,207	$8,835,023	$3.30
Gulf Total		20,651,245	$60,259,242	$2.92
Northeast[a,b]	MA	149,349	$5,477,147	$36.67
	ME	45,338	$1646154	$36.31
	NJ	550,086	$2,547,127	$4.63
	NY	135,338	$2,870,069	$21.21
	RI	44,083	$1,800,658	$40.85
Northeast Total		924,194	$14,341,155	$15.52
Pacific[b]	AK	24,699	$439,514	$17.79
	CA	1,230,333	$7,367,169	$5.99
	OR	162,063	$2,748,273	$16.96
	WA	10,150,197	$33,338,537	$3.28
Pacific Total		11,542,593	$43,453,979	$3.76
Grand Total		34,539,976	$127,069,368	$3.68

[a] Oysters are also harvested from Connecticut, but NMFS data did not include a harvest number for the state in 2008. In 2007, Connecticut harvested 193,019 meat-weight pounds.

[b] Because these estimates are unusually high, we verified these prices through discussions with industry contacts.

Sources: National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Marine Commercial Landing Statistics. Available at http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html. As obtained on June 15, 2010.

Alaska Department of Fish and Game, Division of Commercial Fisheries. Statewide Aquatic Farming Production and Value. Available at http//www.cf.adfg.state.ak.us/geninfo/enhance/maricult/aqfarm_i/90-09farm.htm. As obtained on June 15, 2010. (To calculate the harvest volume for Alaska, we converted the provided value of 800,244 oysters to meat-weight pounds by multiplying by 14 grams.)

Service (NMFS). Based on these data, the Gulf dominates oyster harvests with 59% of harvests compared with the Northeast at nearly 2%, the Pacific at nearly 34%, and the Atlantic at 4% in 2008 (see Figure 2-2). Over the past few years, Gulf, Atlantic, and Northeast harvests have decreased relative to 2000, and Pacific harvests have increased (see Figure 2-3).

Prices for harvested oysters, based on meat-weight yields, are in the range of $2 to $3 per meat-weight pound in the Gulf and Pacific regions (see Table 2-1). Prices are higher in the Atlantic and Northeast.

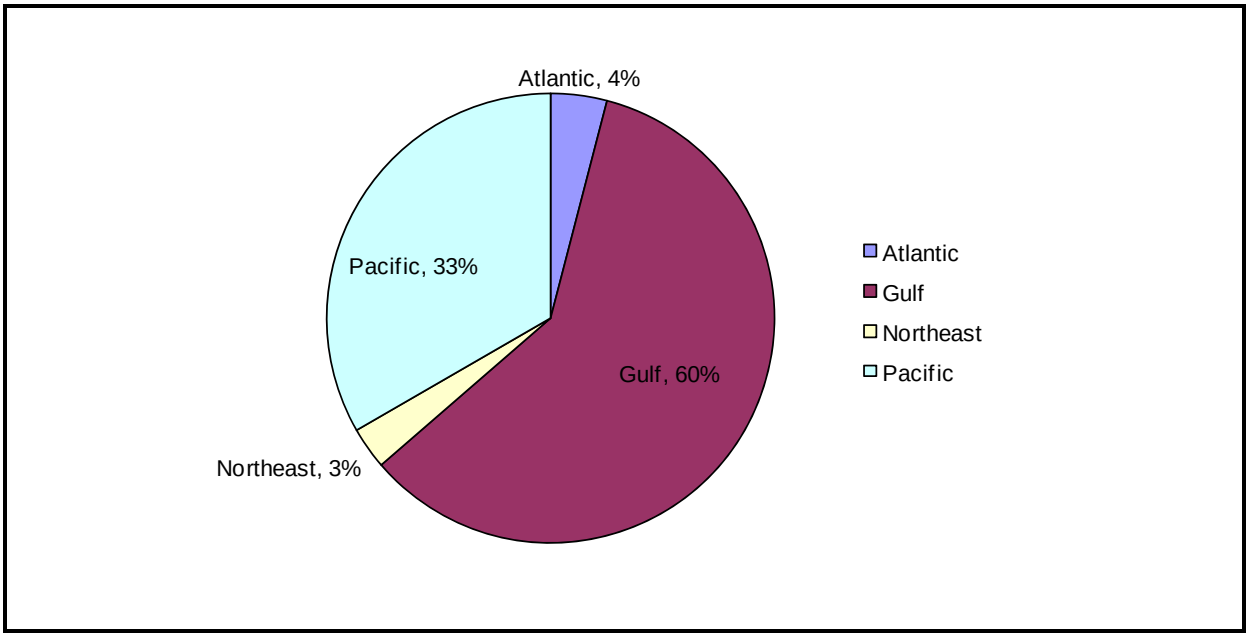
As noted in Muth et al. (2000), NMFS harvest volumes may be underreported in most regions of the United States for the following reasons:

- Harvesters are taxed on volumes of harvests and associated profits; thus, they may underreport their volumes.
- In some states, harvesters may sell shellstock directly without going through a dealer (who reports the harvest volume).
- The meat yield conversions used by the states may be outdated or inconsistent between regions.
- The harvest containers used by individual harvesters may differ from the standard used by the states to calculate yields.

To the extent that the underreporting of harvests is consistent over the course of the year, the harvest data still provide us with some general information about seasonal harvests and prices.

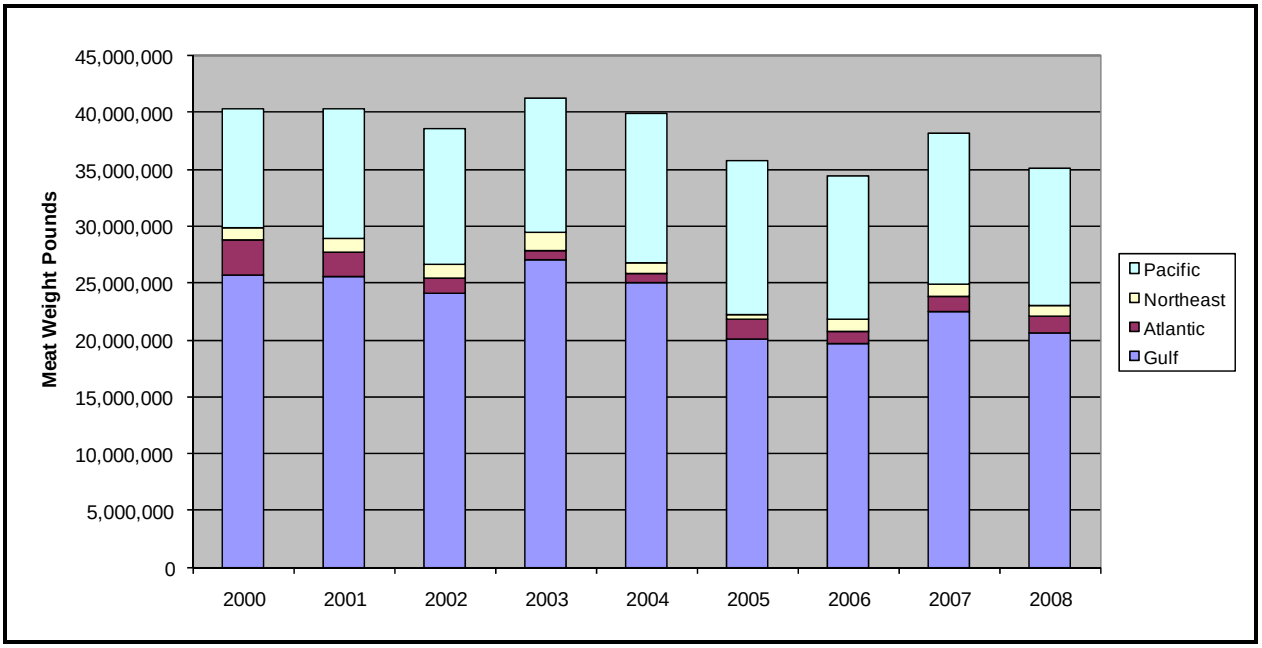
Figure 2-4 presents oyster harvests by month for 2008. As indicated by these data, nationwide harvests are at their peak in October through March. The summer months from June through September, when oysters are spawning, yield lower harvest numbers. Figure 2-5 presents monthly oyster harvest values by month for each region in 2008. Prices are relatively stable throughout the year in the Gulf and the Pacific but exhibit seasonal variability in the Atlantic and the Northeast. Prices are highest in the summer in the Atlantic and in the winter in the Northeast.

Figure 2-2. Nationwide Oyster Harvests by Region, 2008
The Gulf region dominates U.S. oyster harvests.



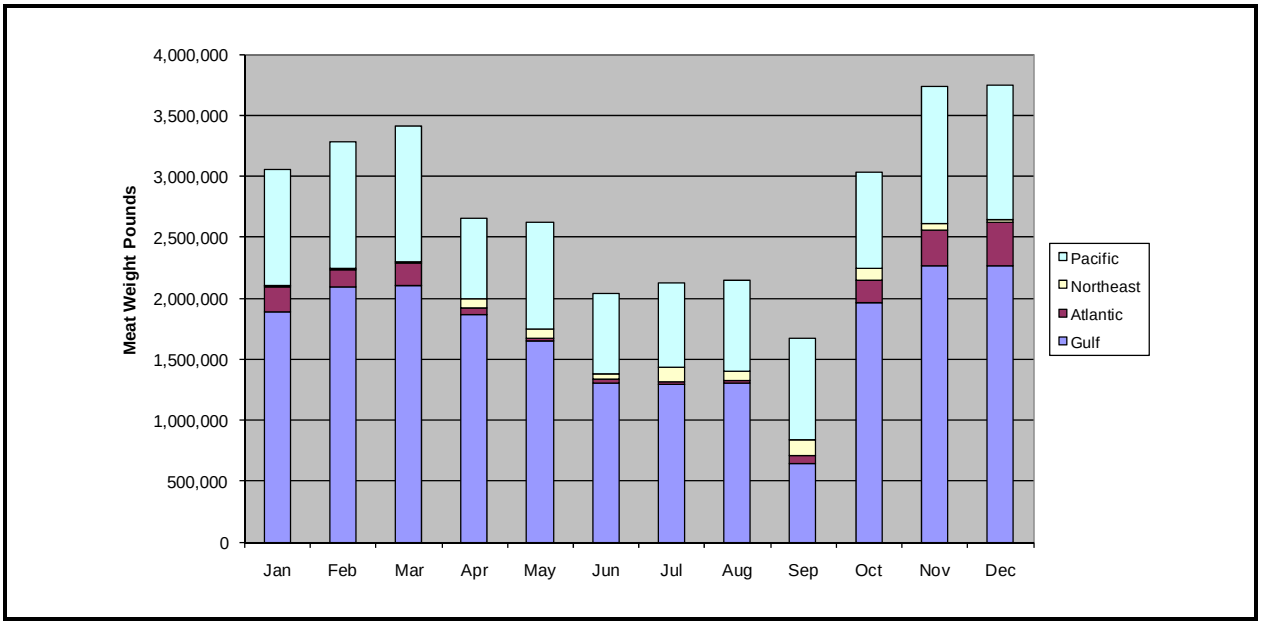
Source: National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Marine Commercial Landing Statistics. Available at http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html. As obtained on June 15, 2010.

Figure 2-3. Nationwide Oyster Harvests by Region, 2000–2008 (Meat-Weight Pounds)
Gulf, Atlantic, and Northeast oyster harvests have decreased while the Pacific harvest has increased.



Source: National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Marine Commercial Landing Statistics. Available at http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html. As obtained on June 15, 2010.

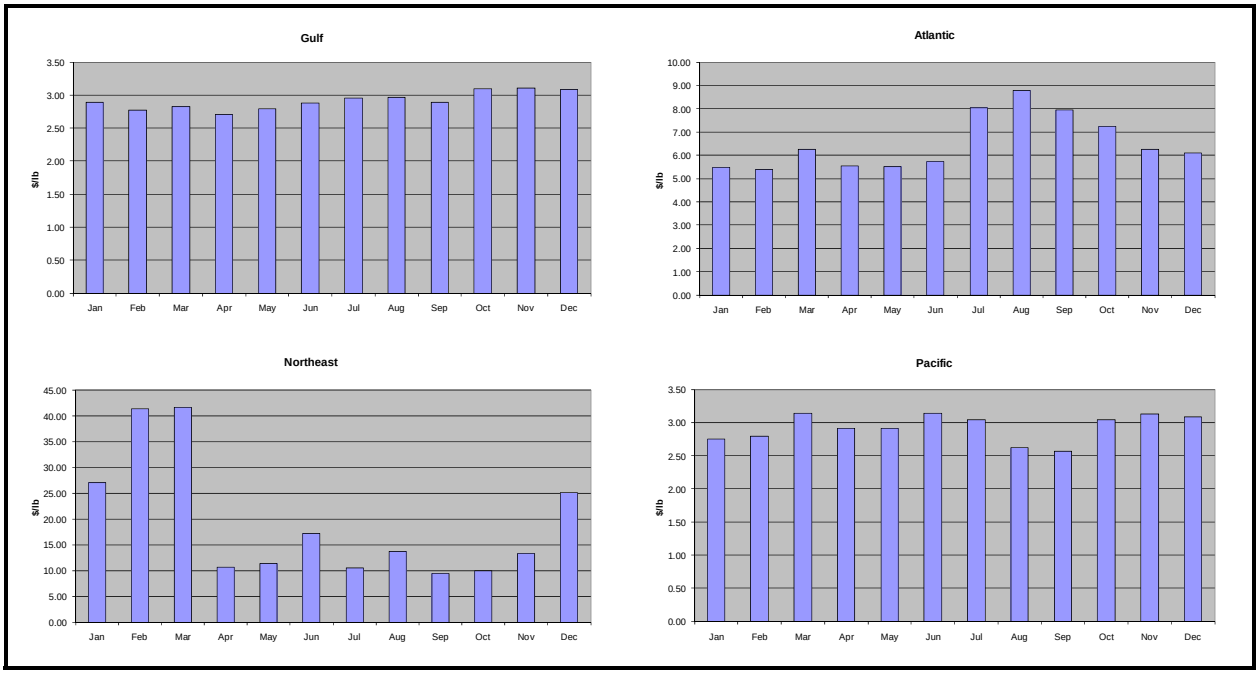
Figure 2-4. Regional Oyster Harvests by Month, 2008[a] (Meat-Weight Pounds)
Oyster harvests are at their peak during the holiday months of November and December.



[a] Portions of the Northeast harvests (135,000 pounds) and Pacific harvests (1.4 million pounds) are not specified by month.

Source: National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Marine Commercial Landing Statistics. Available at http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html. As obtained on June 15, 2010.

Figure 2-5. Regional Oyster Harvest Values by Month, 2008 ($ per Meat-Weight Pound)



Source: National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Marine Commercial Landing Statistics. Available at http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html. As obtained on June 15, 2010.

2.1.1 Gulf States

The Gulf States—Alabama, the west coast of Florida, Louisiana, Mississippi, and Texas—annually produce over 600 million oysters. Each Gulf state has varying practices and regulations that guide their oyster industry, though all states must follow the NSSP guidelines at a minimum. Figure 2-6 shows a map of the Gulf states with the major harvesting areas for each state.

Figure 2-6. Map of the Gulf States

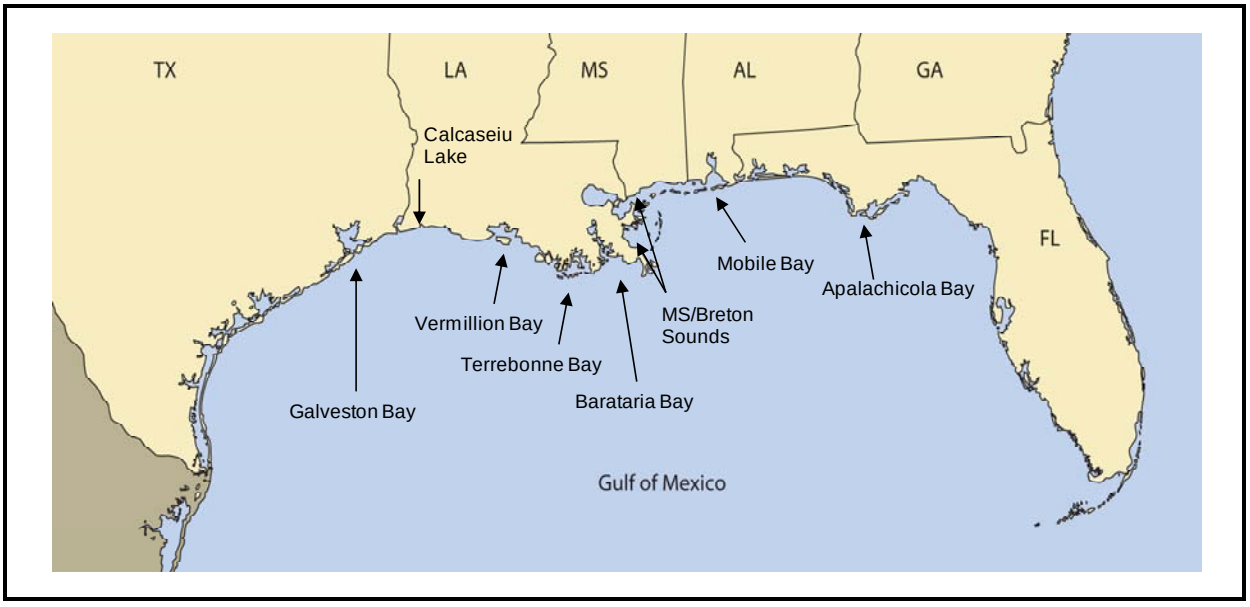


Table 2-2 provides harvest volumes from each Gulf state and the estimated percentage of oysters consumed on the half shell and shipped interstate during the summer. Almost 10 million meat-weight pounds of oysters were harvested from the Gulf during the summer months (April through October) in 2008.

Based on information obtained from state agencies and industry participants, an estimated 40% of Florida-West Coast, 70% of Louisiana, and 75% of Texas oysters harvested from the Gulf in the summer months (April through October) are used for half-shell consumption. Essentially no oysters harvested from Alabama and Mississippi in the summer are used for half-shell consumption. Relative to the total harvest, an estimated 30% of Florida-West Coast, 75% of Louisiana, and 50% of Texas oysters harvested from the Gulf in the summer and intended for half-shell consumption are shipped interstate (and thus are

Table 2-2. Gulf Harvest Volumes by State, Summer 2008

	Alabama	Florida-West Coast	Louisiana	Mississippi	Texas	Total
Percentage of total harvest used for half-shell consumption in the summer[a]	0%	40%	70%	0%	75%	
Percentage of total harvest shipped interstate (applies to half-shell oysters)[a]	NA	30%	75%	NA	50%	
Harvest volumes: Summer 2008 (April–October)						
Meat-weight (pounds)[b]	30,929	1,297,429	6,779,514	1,009,136	914,152	10,031,160
100-pound sacks	7,732	324,357	1,694,879	252,284	228,538	2,507,790
No. of oysters[c]	1,933,063	81,089,313	423,719,625	63,071,000	57,134,500	253,608,958

[a] Percentages obtained through discussions with state agencies and industry experts, all of which were generally in agreement.
[b] Harvest data were obtained from the NMFS.
[c] The number of oysters is calculated by assuming 4 lbs of meat-weight per 100 lb sack, and 250 oysters per sack. The estimated meat-weight pounds per sack for summer-harvested oyster are based on estimates provided by several industry participants.

specifically subject to PHP requirements). Estimates of interstate shipments are not included for Alabama and Mississippi because shucked product will not be subject to PHP requirements.[1] We discuss each state below, in alphabetical order.

Alabama

Alabama has three harvesting areas: Mobile Bay, portions of Portersville Bay and Grand Bay, and Bon Secour Bay. In Alabama, harvesters primarily use tongs to harvest, though a small number of dredge licenses are granted for private leases. Boats with dredges are limited to 16 sacks of harvested oysters per day. Oysters must be tagged upon harvest. Tags can be purchased from the Alabama Department of Conservation and Natural Resources (ADCNR) for $0.25 per tag (ADCNR, January 2010).

[1] To determine the percentage of half-shell oysters shipped interstate, one would multiply the percentage intended for half-shell consumption by the percentage shipped interstate. For example 52.5% of oysters (75% of 70%) harvested in Louisiana are shipped out of state for raw half-shell consumption, and the remainder is used for raw half-shell consumption within Louisiana or shucking.

The oyster industry in Alabama was decimated after hurricanes in 2004 and 2005, losing almost all of their public reefs to saltwater intrusion (Felsher, 2009). This was followed by 3 years of drought, which allowed a destructive marine snail to attack the remaining oysters. The state of Alabama has efforts underway to revitalize the oyster industry by creating a new 800-acre reef in Mobile Bay (ADCNR, April 2010).

Alabama adopted new time-temperature regulations in May 2010. During the months of May through October, oysters may be harvested between 7:00 am and 2:00 pm and must be refrigerated within 4.5 hours of harvest. During all other months of the year, oysters must be refrigerated within 8 hours of harvest. In all months, oysters must be cooled to 55°F within 4 hours.

Florida

Approximately 80% of Florida oysters are harvested in the Apalachicola Bay area, which includes the waters of St. George Sound and St. Vincent Sound. This area covers about 210 square miles, comprising about 7,000 acres of public reefs and 600 acres of private reefs (City of Apalachicola, 2006). Cultured oysters can be harvested at any time, but some time-of-year restrictions apply to wild oysters. As in Alabama, Florida harvesters can only use tongs when working public waters (Felsher, 2009). Oystermen are allowed to harvest up to 20 bags per day.

The proportion of harvested oysters that are shucked varies by season and location. For example, approximately 80% are shucked in Cedar Key and St. Augustine, but in other parts of the state more than 50% are left on the half shell. Less than 50% of half-shell oysters are shipped out of state.

Florida recently updated their time-temperature requirements, as outlined in Table 2-3.

Table 2-3. Time-Temperature Requirements in Florida
These requirements became effective on April 26, 2010.

Cooling Option	Harvest Times	Time to Refrigeration	Cooling Time
Traditional	Sunrise to 11:30 am or sunrise to 12:00 pm[a]	4–5 hours	8 hours to 55°F
Rapid cooling[b]	Sunrise to 2:00 pm	7 hours	2 hours to 55°F
Partial on-board cooling	Sunrise to 3:00 pm	8 hours (1 hour maximum time unrefrigerated)	7 hours to 65°F, 9 hours to 55°F
On-board cooling	Sunrise to 4:00 pm	9 hours (1 hour maximum time unrefrigerated)	9 hours to 55°F

[a] Oysters must be delivered to a certified dealer by 11:30 am during the months of May, June, and July; by 12:00 pm during the months of August, September, and October; and by 10:00 pm during the months of November, December, January, February, and March. During the month of April, oysters must be delivered to a certified dealer within 12 hours of harvest.

[b] Rapid cooling refers to systems that use ice, mechanical refrigeration, or vacuum cooling to cool oysters.

Source: Florida Comprehensive Shellfish Control Code.

Louisiana

Louisiana contributes up to 40% of all oyster harvests in the nation each year (Felsher, 2009). More oysters are harvested in Louisiana than any other Gulf state, with over 1.6 million acres of leases (Buskey, 2010). Approximately 400,000 of these acres are held in private leases (Felsher, 2009). Private leases in Louisiana account for about 60% of total oyster harvests (Banks, 2010). During the summer months in Louisiana, only private leases are open, whereas all public beds are closed from April 30 through October 15 every year for resource replenishment (Leblanc, 2010).

During the summer months, most of the oysters harvested in Louisiana are for the half-shell market. Approximately 75% of all oysters are shipped out of state.

Louisiana harvesters face new time-temperature regulations that went into effect on May 1, 2010. During the months of December, January, and February, harvesters must refrigerate their oysters within 36 hours. In March, April, and November, oysters must be refrigerated within 8 hours, and from May through October, oysters must be refrigerated within 1 hour of harvest and cooled to 55°F within 6 hours.

The Louisiana oyster industry has struggled over the past 5 years, with Hurricanes Katrina and Rita making landfall in 2005

and Hurricanes Gustav and Ike making landfall in 2008. Hurricanes Katrina and Rita affected two-thirds of Louisiana's oyster beds either catastrophically or significantly (Louisiana Oyster Task Force, 2005).

Mississippi

The Mississippi seafood industry was devastated by Katrina in 2005 and has not fully recovered. Oyster mortality was estimated between 90 and 95% on the major commercial reefs during Hurricane Katrina (Mississippi Department of Marine Resources, 2007). Rebuilding of oyster reefs has been ongoing by the Mississippi Department of Marine Resources.

The Mississippi Department of Marine Resources manages 17 natural oyster reefs. Approximately 97% of the commercially harvested oysters in Mississippi come from the reefs in the western Mississippi Sound, primarily from the Pass Marianne, Telegraph, and Pass Christian reefs.

During the months of May through October, public grounds in Mississippi are closed for resource management, but private leases remain open. Both public and private grounds are open November through April.

In the summer, 100% of harvested oysters are shucked. Almost all of the harvested oysters are shipped intrastate.

For the 2010 season, no oysters were harvested from May through September because of the oil spill. For the month of October 2010, time-temperature requirements were put into place to allow harvests from 6:00 am to 1:00 pm with oysters intended for the half-shell market to be refrigerated within 1 hour of harvest and cooled to 50°F within 6 hours.

Texas

In the months of May through October, all oyster harvesting in Texas occurs in the Galveston Bay area. Galveston Bay is the only area in Texas with private leases, which are leased from the state. All other oyster harvesting areas are open November through April. Approximately 75% of oysters harvested in Texas are served on the half shell, and 50% of half-shell oysters are shipped intrastate.

New refrigeration requirements for oysters went into effect May 1, 2010. The time requirements from harvest to refrigeration are as follows: 4 hours in May, 3 hours in June, 1

hour in July and August, 3 hours in September, 4 hours in October, 14 hours in April and November, and 18 hours in January, February, March, and December. For all months, oysters must be cooled to less than 55°F within 6 hours.

Hurricane Ike made landfall in Galveston, Texas, on September 13, 2008, and had a severe effect on the oyster industry. Private leases in Galveston Bay were closed through November 6, 2008, and public leases in Galveston Bay were closed through November 26, 2008 (Robinson, 2010).

2.2 PROCESSING

The processing sector is the post-harvest industry that essentially transforms shellstock oysters into various consumer forms. Harvest and post-harvest operations occur with varying degrees of vertical integration depending on the region of the country. A fully integrated company may do everything from managing their own "seed" operations, through growing and harvesting, to shucking, sorting, and delivery to wholesalers or even retailers. Oyster processors may obtain shellstock directly from harvesters or from wholesalers (see Figure 2-1). Occasionally, processors purchase shucked oysters from other processors for use in prepared oyster products. Also, some facilities engage in both wholesaling and processing activities. Once oysters arrive at a processing plant, they are refrigerated as they await processing.

Processing plants may shuck shellstock oysters and place them into any of several different sizes and types of containers for sale to restaurants, retailers, or other processors. Shucking is currently done by hand. Shuckers of Eastern oysters usually average about 1 gallon of oysters per hour, although an experienced shucker can produce twice that volume. Shuckers of Pacific oysters may open from 10 to 25 gallons per day depending on their experience and the size of the oysters and meat-weight (Dewey, 2000). Some processing plants also conduct further processing of shucked oysters such as breading, stewing, or freezing (Anderson et al., 1996).

When oysters intended for the half-shell market are processed, they are usually placed on a conveyor belt where workers sort, grade, and wash them. Next, workers weigh or count them and pack them into cardboard boxes or burlap sacks. At this point, workers place a new tag on each batch of oysters. Processors

must keep the original tags, which record the harvester and location of harvest, on file for 90 days. The new tags include information from the original tags plus additional information from the processor. Each state requires these tags and must address NSSP requirements. With the new time-temperature requirements, tags are color coded based on whether they can be served raw on the half shell or whether they must be post-harvest processed or shucked. For example, in Louisiana, sacks of oysters with a white tag inform customers that the oysters were harvested in compliance with the time-temperature guidelines and can be consumed raw on the half shell. Oyster sacks with a blue tag inform customers that the oysters were not harvested in compliance with the time-temperature guidelines but have been through a post-harvest process and, thus, can be consumed raw. Oyster sacks with a green tag inform that the oysters must be shucked or post-harvest processed (Louisiana Department of Wildlife and Fisheries [LDWF], no date).

Many oyster processors produce both shucked and half-shell oysters. The proportion of oysters used in each form is extremely difficult to determine given data limitations and varies by plant, state, season, and year. Table 2-4 indicates the assumptions we used in our analysis about the proportion of shellstock going to each market by Gulf state as suggested by our industry contacts. Processors continually adjust the proportion of each form produced based on demand. In the Gulf, half-shell demand is generally higher in the summer and shucked demand is generally higher in the winter, but significant sales of each occur in all seasons.

Table 2-4 also displays the estimated percentage of oysters that are shucked versus sold on the half shell, by Gulf state. In Alabama and Mississippi, all oysters are shucked. In comparison, only one-fourth of oysters are shucked in Louisiana.

Processing plants that ship oysters across state lines must be certified as interstate shippers. Interstate shippers are inspected and certified by individual states. Each state provides its list of certified dealers to FDA, which publishes the Interstate Certified Shellfish Shippers List (ICSSL). Intrastate shippers, which must market their oysters within their state borders, are

Table 2-4. Estimated Proportion of Shellstock to the Shucked and Half-Shell Markets by State in the Gulf Region in the Summer
Percentages of shellstock oysters for shucked and half-shell use vary by state because of differences in the shellstock resource.

State	Shucked	Half Shell
AL	100%	0%
FL	50–80%	20–50%
LA	25%	75%
MS	100%	0%
TX	50%	50%

Source: From state interviews.

inspected and certified by individual states. However, most states do not maintain a separate intrastate list and, thus, require all plants to be certified interstate shippers. The state agencies involved include departments of health, marine resources, agriculture (especially in states where all production is aquaculture), natural resources, or fisheries and wildlife.

Table 2-5 indicates the number of interstate certified shellfish shippers and shucker-packer plants, excluding operations that appear to be food service and retail grocery distributors. Repackers and reshippers, which are also included on the certified shippers list, are not included because they would be only indirectly affected by post-harvest treatment requirements.

Table 2-5. Locations of Shellfish Shippers in the Gulf Region by State
The number of interstate shellfish shippers provides an upper bound on the number of oyster plants.

State	Interstate Shippers[a]		Grand Total
	Shellfish in Shell	Shucker/Packer	
AL	1	26	27
FL	53	28	81
LA	45	36	81
MS	14	4	18
TX	3	8	11
Gulf Total	102	116	218

[a] Information on interstate shippers was obtained from the U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. Interstate Certified Shellfish Shippers List.

Certified shellfish shippers may handle one or more of the following: oysters, clams, mussels, and scallops. Although the shippers list does not indicate the type of shellfish handled by these plants, it is believed that the majority handle some volume of oysters. The precise number of shellfish plants that handle oysters is not known; thus, the certified interstate

shellfish shippers list provides an upper-bound estimate of the number of oyster plants.

NMFS maintains confidential information on the numbers, locations, and volumes of processed product produced by plants that shuck or otherwise process oysters. These data, aggregated by NMFS to preserve confidentiality, are presented by Gulf state for 2008 in Table 2-6. In 2008, NMFS estimates include 59 oyster-shucking plants in the Gulf states that produced over 13 million pounds of shucked meat and employed over 1,200 employees. Nearly all of these plants probably also handle half-shell product. However, we believe that the number of oyster plants that handle only half-shell oysters greatly exceeds the number of oyster-shucking plants and that average production (on a meat-weight basis) and employment for these plants are lower than the averages for oyster-shucking plants.

Based on the reported values for the output, we also calculated the average wholesale price per pound of output by state and region. Shucked product prices are highest in Texas and lowest in Mississippi, ranging from $3.03 to $5.30 per pound.

NMFS does not maintain data on the volume of half-shell product handled by plants that shuck oysters and does not maintain data on plants that handle *only* half-shell product. Thus, volume data on half-shell oyster plants are not presented here.

In our previous report to FDA (Muth et al., 2000), RTI obtained wholesale prices on both half-shell and shucked product from the Fulton Fish Market reports. This source is no longer available for oysters. In 1997, per-oyster prices ranged from 19.5 to 21.2 cents in Gulf states, compared with 27.25 to 38 cents in the Northeast. It is likely that prices in the Northeast for both shucked and half-shell product continue to be higher than in the Gulf.

Table 2-6. Oyster Processing and Shucking Plants by Gulf State, Employment Volumes, and Values as Reported by NMFS, 2008
Alabama shucks the greatest volume of oysters followed by Louisiana and Mississippi.

	Shucked				
State	**No. of Plants**	**Employment**	**Pounds**	**Value ($)**	**($/lb)**
AL	29	464	4,767,649	24,038,826	5.04
FL[a]	8	168	1,635,375	7,548,891	4.62
LA	9	246	2,596,074	9,522,117	3.67
MS	3	88	2,479,357	7,521,224	3.03
TX	10	282	2,206,025	11,686,823	5.30
Total	59	1,248	13,684,480	60,317,881	4.41

[a] Information for Florida is provided for the Gulf Coast only.

Source: NMFS data provided by Alan Lowther.

2.3 INTERREGIONAL AND INTERNATIONAL TRADE

Data on interregional and international trade in oyster products are included here because post-harvest treatment requirements for Gulf oysters may potentially alter trade flows of oyster products.

Based on information provided by industry representatives, shellstock may be transported between states and between regions for processing, and processed product may be shipped elsewhere for consumption. Since 2003, the state of California prohibits all Gulf Coast oysters harvested in the summer months that are not post-harvest processed. Thus, many of the Gulf post-harvest processors ship their treated product to California to meet their demand. In general, it appears that interregional shipments of oysters are substantial and are likely to continue to be substantial in the future.

Table 2-7 provides data on imports of oyster products from 2005 to 2009 for the top five countries from which we import and overall import totals. The volumes presented are for pounds of oysters in the shell, shucked, or otherwise processed and, thus, can only be used as a general indication of the volume of oyster product imported. If all volumes were oyster meat volumes, international imports would be approximately 23% of the U.S. harvest volume. According to the interstate shippers list, Canada, New Zealand, and Mexico have plants

Table 2-7. Imports of Oyster Products, 2005–2009 (Pounds of Oysters)
Import volumes for oyster products have decreased over the past 5 years with Canada and South Korea accounting for the vast majority of imports.

Country	2005	2006	2007	2008	2009
Canada	5,443,101	5,427,065	4,920,093	3,644,075	3,379,972
China	351,828	212,577	279,499	314,019	218,343
Japan	307,432	448,804	170,871	129,870	491,387
Mexico	628,742	438,576	844,483	919,135	1,318,992
South Korea	3,285,623	4,386,698	3,528,137	3,064,375	3,444,254
All other	190,198	512,300	74,377	33,248	49,357
Total volume	10,206,924	11,426,020	9,817,460	8,104,722	8,902,305
Total value	$20,470,144	$25,112,747	$22,987,141	$16,686,640	$20,032,804

Note: Import volumes combine farmed and wild oysters that are live, fresh, frozen, dried, salted, and brined.

Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service, Office of Science and Technology, Fisheries Statistics Division. U.S. Foreign Trade—Annual Trade Data by Product, Country/Association. Available at http://www.st.nmfs.gov/st1/trade/annual_data/TradeDataAnnualProductCountry.html. As obtained on June 21, 2010.

currently certified to ship shellfish in the shell to the United States, and Canada, South Korea, and New Zealand have plants currently certified to ship shucked shellfish to the United States. The number of certified shippers of each type for each country is provided in Table 2-8.

Table 2-8. Certified Foreign Shellfish Shippers, November 2009
Foreign shellfish plants that export oysters to the United States must be certified interstate shippers.

Country	Shellfish in Shell	Shucker/Packer	Total
Canada	56	68	124
Mexico	4	0	4
New Zealand	2	27	29
South Korea	0	5	5
Total	62	101	163

Source: U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition. November 2009. Interstate Certified Shellfish Shippers List. Available at http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FederalStatePrograms/InterstateShellfishShippersList/default.htm.

Table 2-9 provides data on exports of oyster products from 2005 to 2009 for the top five countries to which we export and overall export totals. Similar to imports, the indicated volumes may be for in the shell, shucked, and otherwise processed oysters. If all volumes were oyster meats, exports would account for approximately 20% of the U.S. harvest volume.

Table 2-9. Exports of Oyster Products, 2005–2009 (Pounds of Oysters)
Export volumes for oyster products have remained fairly constant over the past 5 years with Canada and China accounting for approximately three-quarters of exports.

Country[a]	2005	2006	2007	2008	2009
Canada	2,311,705	1,855,565	2,183,913	2,865,258	2,946,506
China	3,846,561	3,060,666	2,422,534	2,496,876	2,201,982
France	516,027	139,350	382,729	327,709	179,636
Singapore	46,796	106,898	135,548	172,053	237,853
United Kingdom	32,274	—	142,456	235,906	—
All other	1,026,931	1,042,903	912,120	1,086,509	800,228
Total volume	7,780,294	6,205,382	6,179,300	7,184,311	6,366,205
Total value	$17,899,395	$14,940,557	$17,096,188	$20,164,228	$19,491,513

Note: Export volumes combine live, fresh, frozen, dried, salted, and brined oyster products.

[a] The five countries with the highest export volumes in 2008.

Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service, Office of Science and Technology, Fisheries Statistics Division. U.S. Foreign Trade—Annual Trade Data by Product, Country/Association. Available at http://www.st.nmfs.gov/st1/trade/annual_data/TradeDataAnnualProductCountry.html. As obtained on June 22, 2010.

3 Post-harvest Processing Methods and Consumer Acceptance

RTI evaluated five PHP methods that are intended to eliminate *Vibrio vulnificus* from raw oysters. These treatment technologies are HHP processing, cool pasteurization, irradiation, IQF with extended storage, and high-salinity treatment. Three of the five treatment technologies are currently in use in the Gulf for Eastern oysters (*Crassostrea virginica*), and products from plants using these treatment technologies are already being sold to restaurants, grocery stores, and other food service establishments. The other two technologies have been demonstrated to be effective in eliminating *Vibrio vulnificus* but have not been commercially applied yet.

In this section, we provide descriptions of the PHP methods, validation and verification of post-harvest processes, and consumer acceptance of post-harvest processed oysters.

3.1 DESCRIPTION OF PHP METHODS

In this section, we describe the five post-harvest processes that have been demonstrated to reduce *Vibrio vulnificus* levels to a nondetectable level in oysters: HHP, cool pasteurization, irradiation, IQF with extended storage, and high-salinity treatment. We also discuss the applicability of each of the technologies for PHP requirements.

3.1.1 HHP Processing

HHP is currently used by three oyster operations in the Gulf—two in Louisiana and one in Texas.

HHP is a method of inactivating microorganisms in foods by subjecting them to very high pressure. The process was developed and patented for oysters by Motivatit Seafoods, L.L.C. in Houma, Louisiana, in 1999. Prior to processing, oysters intended for the raw half-shell market are individually banded using a shrink wrap band. Workers put bands around each oyster on a conveyer that passes briefly under a heater. Workers load oysters for both raw half-shell and shucked uses into baskets, and a system of overhead rails conveys the baskets to the ultra high-pressure processor. The baskets are hoisted up and then lowered into the water-filled pressure chamber, which is then sealed and pressurized using an electric 60 horsepower pump. Pressures of 35,000 to 40,000 psi are applied for 3 to 5 minutes. The process can be used for both half-shell and shucked oysters. For oysters intended for shucking, the pressure helps release the adductor muscle from the shell, making it easy to remove the oyster from the shell. Following treatment, oysters intended for the raw half-shell market are boxed and iced with their bands on, and oysters intended for shucking are shucked and packed in containers.

Recently, Motivatit Seafoods released their licensing rights to Avure Technologies, an HHP equipment manufacturer. Avure currently sells five different sizes of HHP equipment, ranging in capacity from 35 liters to 687 liters (or 50 to 700 pounds of oysters per cycle, respectively). Table 3-1 shows the dimensions and capacity level for each size machine. Processors can purchase either vertical or horizontal systems, depending on the capacity level desired. Vertical systems use hoists to lift the oysters in and out of the equipment, whereas horizontal systems use conveyors to load product in one side and out of the other side. Avure estimates that the average life cycle of their HHP equipment is approximately 10 years. They provide a 1-year or 100,000-cycle warranty with the purchase of an HHP system.

Currently three Gulf oyster processors use HHP on oysters—two in Louisiana and one in Texas. In addition, one processor in Washington State uses HHP for oysters.

Table 3-1. Dimensions and Capacity Levels of HHP Equipment

	35 L[a]	100 L	320 L	350 L	687 L
Dimensions	12 ft x 12 ft x 13 ft (height)	30 ft x 20 ft x 6 ft (height)	20 ft x 30 ft x 23 ft (height)	50 ft x 20 x 7 ft (height)	40 ft x 30 ft x 7 ft (height)
Position	Vertical	Horizontal	Vertical	Horizontal	Horizontal
Cycles per hour	9	11	12	12	10
Capacity per cycle (in-shell weight)	50 lbs	120 lbs	450 lbs	500 lbs	700 lbs

[a] The 35 L machine is currently economically infeasible for oysters because the cost of the machine ($700,000) is extremely high relative to its capacity.

3.1.2 Cool Pasteurization

Cool pasteurization is currently used by one oyster operation in the Gulf.

The pasteurization of oysters as a post-harvest process was developed and patented in 1995 by AmeriPure in Franklin, Louisiana. Cool pasteurization is a mild thermal treatment of oysters in the shell, followed by a rapid cooling. This process raises the temperature of the oyster enough to kill *Vibrio vulnificus* bacteria but does not sterilize or cook the oyster.

To treat oysters, the oysters are first washed, then individually banded with rubber bands and loaded onto trays. The trays are loaded onto carts, which are hoisted into a tank containing warm (126°F) water for 24 minutes. The trays are then hoisted into a cool water tank for 15 minutes at 40°F. The oysters are then packed for half shell or shucked. The two tanks hold 7,500 and 5,500 gallons of water, respectively, and can process 10,500 oysters per cycle. Following processing, half-shell oysters are boxed and iced for shipment.

AmeriPure is currently the only Gulf oyster processor that uses the cool pasteurization technology. They operate one facility in Franklin, Louisiana, and have plans to move to a new facility in Myrtle Grove, Louisiana.

3.1.3 Low-Dose Gamma Irradiation

Irradiation has not yet been applied commercially to Gulf oysters, but the process has been approved by FDA.

Irradiation of oysters has been approved by FDA as a post-harvest process and validated by researchers at the University of Florida, although the process is not yet commercially used for oysters. Irradiation involves exposing oysters to ionizing energy, either gamma rays, machine generated electrons, or X-rays. Gamma rays are more commonly used, specifically cobalt

60. The gamma rays interact with water and other molecules in the oyster, thereby inactivating bacteria.

Large quantities of oysters can be irradiated quickly within packaged boxes. It would be the last step in the process before oysters are introduced into commerce. In trials, oysters are cleaned, packaged, and labeled, and then shipped to the irradiation facility on pallets in refrigerated trucks.[1] The irradiation facility does not need to hold oysters, because they can process an entire truckload in only 1 hour. Thus, the oysters are transported to and from the irradiation facility on the same truck. Oysters have an expected 7- to 10-day shelf life after irradiation.

Currently one irradiation facility operates in the Gulf—Food Technology Service, Inc. (FTSI), located in Mulberry, Florida. Their facility is a Hazard Analysis and Critical Control Point (HACCP)-certified seafood plant. FTSI has plans to irradiate oysters from other shellfish processors in packages that have been prelabeled as irradiated at the primary producer's facility. However, this presents a violation of federal labeling laws, because the product would be misbranded as it crosses state lines prior to irradiation. In a letter from FDA to the Florida Department of Agriculture and Consumer Services, FDA writes that it may "consider exercising enforcement discretion" in this case under certain conditions. These conditions include written and signed agreements between FTSI and the primary processor, with each party having an approved HACCP plan that allows for sealed trucks, palletizing specifications, labeling of pallets of oysters to be irradiated, and proper record keeping (DiStefano, 2009).

3.1.4 Individual Quick Frozen (IQF) with Extended Storage

IQF is currently used by several oyster operations in the Gulf with at least one operation in each Gulf state.

Freezing oysters to increase shelf life was first applied in 1989. Cryogenic freezing with extended storage decreases *Vibrio vulnificus* to nondetectable levels. After incoming shellstock has been received, rinsed, and prepared for treatment, oysters are shucked and placed on the half shell. Workers load the oysters onto a conveyor belt that transports them through the freezer tunnel where they are rapidly frozen using liquid carbon dioxide or nitrogen. Next, they travel on the conveyor belt through a glazing machine that sprays them with a fine mist of water,

[1] Banding the oysters would likely be needed for commercially irradiated product.

which freezes into a glaze of ice. Workers then pack the frozen oysters into wax-coated corrugated boxes using sheets of plastic to separate layers and bubble wrap to add cushioning. The entire process takes approximately 9 minutes from start to finish. Once treated, the oysters are stored in a freezer for a period of time sufficient to achieve nondetectable levels of *Vibrio vulnificus*.

One of the benefits of the IQF process is that oysters can be stored from the winter harvest, which yields higher quality oysters (particularly in the Gulf), and then offered for sale during other times of the year.[2] More importantly, however, raw half-shell oysters can be served at restaurants and other food service establishments without a shucker on staff. The oysters are removed from their packaging and brought up to the desired serving temperature before they are served on the half shell. This means that raw half-shell oysters can be made available in locations where they otherwise would not be.

Several oyster processors in the Gulf now operate IQF processes (two in Texas, one in Louisiana, one in Mississippi, one in Alabama, and four in Florida). This is a substantial change from 10 years ago when only one major oyster processor in the Gulf was operating an IQF process.

Because use of IQF for summer-harvested Gulf oysters does not typically result in an acceptable product for the consumer, we assumed that oyster processors would not install IQF equipment in response to a requirement to treat oysters with a PHP method.

Based on our evaluation, we have determined that IQF is not a viable option for PHP of Gulf oysters harvested during the summer because of quality issues. IQF is used to treat winter-harvested oysters that are then sold throughout the year.[3] Gulf operations that have IQF equipment very rarely freeze summer-harvested oysters, thus providing evidence that consumer acceptance issues make the use of IQF in the summer infeasible. Oysters are thinner because of spawning; thus, the process results in unacceptable product. Industry contacts made the following statements regarding summer-harvested IQF oysters:

- not a good firm product to freeze
- visual aesthetics are not acceptable
- grainy or poor texture

[2] However, freezing oysters alters the texture of the meat; thus, IQF oysters are a somewhat different commodity than fresh oysters.

[3] Note that oyster processors that operate IQF equipment may freeze oysters at the beginning and end of the summer season (April, May, and October).

- dark color
- "water bags" that do not freeze well

The only exception was that one processor freezes some oysters that have been through HHP because HHP helps summer-harvested oysters withstand the freezing process.

3.1.5 High-Salinity Treatment

High-salinity treatment may be a viable post-harvest process in the future, but additional research and regulatory approvals will be required before it can be implemented.

Research has shown that relaying oysters from their point of harvest to higher salinity waters reduces *Vibrio vulnificus*, thus the term "high-salinity treatment" (Motes and DePaola, 1996; Supan, 2010). The concept of reducing *Vibrio vulnificus* in oysters by using high-salinity waters was first introduced in 1996 (Motes and DePaola, 1996). Results showed that relaying oysters to offshore waters with salinity of 30 to 34 ppt reduced *Vibrio vulnificus* in oysters to less than 10 MPN/g within 7 to 17 days. Researchers at Louisiana State University recently expanded this research, although it was interrupted by the Deepwater Horizon oil spill (Supan, 2010).

Although high-salinity treatment may be a viable treatment technology in the future, not enough research has been conducted to determine its feasibility. Examples of particular issues that still need to be worked out include the following:

- Approved locations for suspending oyster crates or placing oyster crates on shore bottom for a 10- to 16-day period of exposure to high-salinity waters would need to be determined.
- Management and responsibility for the oysters during the high-salinity treatment period would need to be established.
- High-salinity exposure of typical Gulf oysters in the summer may result in high mortality rates unless a schedule for acclimation (and possibly use of specially bred oysters) can be developed such that mortality rates are tolerable.

Furthermore, evaluation of consumer acceptability of a saltier product has only been conducted on a very preliminary basis. Given that it will take some time before it is known whether high-salinity treatment will be commercially viable and acceptable (because of its saltier taste), we excluded it from further analysis in the study.

3.2 VALIDATION AND VERIFICATION OF POST-HARVEST PROCESSES

Validation of post-harvest processes ensures that the processing technique reduces *Vibrio vulnificus* to nondetectable levels. Verification ensures that a previously validated process is working as intended. The NSSP requires validation and verification of post-harvest processes and publishes guidelines for the process in the *NSSP Guide for the Control of Molluscan Shellfish.*[4] In this section, we describe these procedures as outlined in the NSSP.

3.2.1 Process Validation

According to the *NSSP Guide*, process validation is used for initial validation of a process or when there has been a change to a previously validated process. Data on 10 processed samples on 3 separate days (total of 30 samples) are used. All samples on a processing day must come from the same lot of oysters and must be distributed throughout the processing day. A sample consists of a composite of 10 to 12 oysters processed at one time. Initial levels of vibrios in preprocessed oyster samples must be 10,000 MPN per gram or greater. The endpoint criteria for post-processing are less than 30 MPN per gram and a minimum 3.52 log reduction. For the process to be validated, no more than 3 of 30 samples can fail.

3.2.2 Equipment Validation

New or modified equipment must be tested to ensure that it will deliver the validated process. Validation must be accomplished by a physical test of the equipment to ensure that, when properly operated, it will consistently deliver the validated process. Before labeling claims can be made regarding reduction of *Vibrio vulnificus* to nondetectable levels, the process must be verified according to the procedures described below.

3.2.3 Verification

Process verification is used to verify that a previously validated process is working properly. Process verification by

[4] The *NSSP Guide for the Control of Molluscan Shellfish* can be found at http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FederalStatePrograms/NationalShellfishSanitationProgram/ucm046353.htm.

microbiological testing should be done monthly.[5] Monthly sampling should consist of 30 tubes from at least three samples of 10 tubes each with an innoculum of 0.01 grams. Ideally this should be done on 3 separate days spread throughout the month. If this is not feasible, the three samples can be obtained from 3 consecutive days or from three separate lots on the same day. Each sample should contain 10 to 12 oysters. If more than 11 tubes of the 30 most recent 3 to 10 tube samples within any calendar month are positive, then the process fails for that month. Corrective actions must be taken, and verification must be repeated within 1 week of failure.

If all 10 tubes are positive for any given sample, this is considered a failure, and corrective actions must be taken immediately regardless of the result of the other samples for that month. If verification fails twice during a 12-month period, revalidation is required. Each year, dealers are required to evaluate the previous 12 months of data and the HACCP plan. Quarterly sampling may be allowed if the previous 12 verification samples pass.

3.3 CONSUMER ACCEPTANCE OF POST-HARVEST PROCESSED OYSTERS

In this section, we describe oyster consumption, potential consumer reaction to PHP of oysters, potential restaurant and food service manager reaction to treated oysters, and the response to the 2003 ban by California on sales of raw Gulf oysters during the summer.

Product characteristics that influence consumer perceptions of raw half-shell oysters include appearance (size, shape, color), odor, flavor (sweetness and saltiness), and texture (firmness). Consumers prefer cup-shaped oysters and meat that fits the shell (i.e., that is not shrunken). Color may be less important to consumers since there is a great deal of natural variation in the color of raw oysters. Raw oysters should not emit any unpleasant odor because consumers regard off-odor as an indication of spoilage. Fresh oysters should have a mild, salty flavor with no off-flavor, and their texture should be very tender but not mushy (Chen, 1996). The sensory characteristics of half-shell oysters vary depending on the

[5] Monthly verification testing is another cost associated with using PHP methods.

season in which they are harvested, the location from which they are harvested, and the species of the oysters. As shown in Table 3-2, five different species of oysters are harvested in the United States, but the vast majority are *Crassostrea virginia*, also commonly known as the Eastern oyster.

Table 3-2. Species of Oysters Harvested in the United States

Species	Description
Crassostrea virginica	These oysters are known as the Atlantic oyster or the Eastern oyster or may be named for the area where they are harvested (e.g., Bluepoint, Apalachicola, Wellfleet). They are grown on the Gulf Coast and the entire Atlantic Seaboard. They are consumed both raw and shucked.
Crassostrea gigas	These oysters are known as the Pacific oyster and are also sold under a variety of names depending on where they are harvested. They are usually shucked but may also be served on the half shell if they are harvested when small (2 to 3 inches long).
Ostrea lurida	These oysters are known as the Olympia oyster and are native to the Northwest. They are extremely small, approximately the size of a quarter, and are most often served on the half shell. If shucked, 250 meats make up a pint.
Crassostrea sikamea	These oysters, known as the Kumamoto oyster, originated in Japan and are cultivated in the Northwest. They are small oysters, although larger than the Olympia oyster, and are almost always served on the half shell.
Ostrea edulis	These oysters are known as the European flat oyster and are sometimes referred to as the Belon oyster, after the region of France where they originated. They are cultivated in both the Northeast and the Northwest. They have a flat, round shape; are usually harvested when smaller than the Eastern oyster; and are nearly always served on the half shell.

Sources: Rex-Johnson, B. 1997. *Pike Place Public Market Seafood Cookbook.* Berkeley, CA: Ten Speed Press.

Taylor Shellfish. 1999. "Product Catalog, Oysters—Taylor Shellfish." Available at www.taylorshellfish.com/oysters.html. As obtained on December 7, 1999.

CuisineNet. 1999. "Oysters on the Halfshell." Available at wysiwyg://34/http://match.cuisinet/digest/ingred/oyster/eating.shtml. As obtained on December 8, 1999.

3.3.1 Uses and Consumers

Consumers enjoy oysters both in their homes and in restaurants. Most often, oysters consumed at home are cooked, and oysters consumed in restaurants are served either raw or cooked. Consumers purchase oysters from grocery stores or fresh seafood markets for in-home consumption. Oyster processors report that most oysters sold to grocery stores are shucked and shipped in a variety of different size containers for stewing or frying. Although restaurants also purchase shucked oysters, wholesalers and processors report shipping significant quantities of shellstock to restaurants. Consumers order these

oysters in restaurants as raw half-shell oysters or in cooked half-shell dishes such as steamed oysters or Oysters Rockefeller (Anderson et al., 1996).

Although oyster bars and seafood restaurants serving oysters are located in all areas of the country, they are concentrated in coastal regions near oyster landings. During the summer travel and vacation season, consumer demand is high for in-shell oysters suitable for raw or cooked half-shell consumption. Oyster industry representatives report a high consumer demand for shucked oyster meats during the winter holiday season in November and December (Anderson et al., 1996).

Several surveys have been conducted to describe the prevalence of oyster consumption, the characteristics of oyster consumers, and attitudes toward the safety of eating raw oysters. The FDA Food Safety Survey, a nationally representative telephone survey conducted in 2006, reported that 11% of respondents ate raw oysters in the past 12 months (FDA, Center for Food Safety and Applied Nutrition, 2008).

In 2004, ISSC sponsored a telephone survey of 2,006 households in California, Florida, Louisiana, and Texas (ORC Macro, 2005). Twenty-seven percent of Florida and Louisiana households had at least one raw oyster consumer, and California and Texas had a little less than a quarter of households with at least one raw oyster consumer. Slightly more oyster consumers were male (56%). The average age for an oyster consumer was 43 years old, and the median age was 41 years old.

The ISSC survey found that of those respondents who reported eating raw oysters, 68% had eaten raw oysters in the past 12 months, down from 75% as reported in the 2002 survey sponsored by ISSC. Sixty-seven percent of raw oyster consumers reported eating the same amount of raw oysters a year ago, 12% reported eating more, and 21% reported eating fewer. The primary reason cited for eating fewer raw oysters was the unstated "some other reason" (29%) followed by "personal health concerns" (23%) and "availability" (23%). In the 2002 survey sponsored by ISSC, the main reason cited for eating fewer raw oysters was "personal health concerns" (48%). It is interesting to note that the percentage of respondents answering "personal health concerns" decreased between 2002 and 2004, during the same period in which there

were efforts by ISSC to educate at-risk consumers about the risks of consuming raw oysters. These educational efforts were targeted to at-risk consumers, whereas the survey was administered to individuals who consume raw oysters; thus one cannot draw conclusions about the effectiveness of educational efforts on changing risk perceptions based on these findings.

In 2000 and 2001, Mississippi State University (MSU) conducted a mail survey of U.S. residents on the topic of seafood consumption (Hanson et al., 2003). Of the 1,376 respondents, 43% consumed oysters at least occasionally (includes raw and cooked oysters). More males reported consuming oysters compared with females ($p = 0.001$). Oyster consumption was significantly different for income category ($p = 0.001$), with higher oyster consumption reported among the lowest (less than or equal to $10,000) and highest (greater than or equal to $100,000) income categories. Likewise, oyster consumption was significantly different for education level ($p = 0.057$), with oyster consumption higher among respondents who had achieved higher levels of education.

The MSU survey found that oyster consumers reported eating oysters an average of 2.55 times per month. The main reasons for consumption were enjoyment of flavor and addition of variety to the diet. Main reasons for not consuming oysters more frequently were price, product safety, and unavailability of fresh product. Among nonconsumers of oysters, the main reasons for not consuming oysters at all were taste, texture, and smell.

3.3.2 Potential Consumer Reaction to Post-harvest Processing of Oysters

Safety, sensory, and other quality characteristics will affect the demand for post-harvest processed oysters relative to traditional oysters.

Ultimately, the effects of PHP on oyster demand depend on whether consumers prefer or dislike processed oysters compared with traditional oysters. Consumers' specific reactions depend on the following:

- whether consumers are concerned about safety,
- whether changes in the sensory characteristics are acceptable or possibly even preferred, and
- whether other quality changes are associated with treatment (e.g., how the oyster muscle is separated from the shell).

Consumers' responses to each of these factors affect their willingness to pay (WTP) for processed oysters relative to traditional oysters. In general, we expect these effects to be greater for half-shell oysters intended for raw consumption than for shucked oysters intended for cooked consumption. Because cooking kills *Vibrio vulnificus and Vibrio parahaemolyticus* bacteria, safety is less of a consideration for shucked oysters.[6] Furthermore, sensory changes as a result of PHP are more likely to be noticeable for raw half-shell oysters than for shucked oysters that are cooked.

To assess potential consumer response to processed oysters, we conducted a literature review of sensory studies and consumer surveys on PHP of oysters. Table 3-3 provides a summary of the sensory studies that we reviewed, and Table 3-4 provides a summary of the consumer surveys we reviewed.

In 2010, ISSC sponsored a two-part study to assess consumer response to post-harvest processed oysters. Dr. Steven Otwell, University of Florida, led the sensory study and Dr. William Huth, University of West Florida, led the study to estimate WTP for post-harvest processed oysters. The studies were conducted separately to avoid biasing the results of the two studies and to minimize respondent fatigue. For both studies, the study design allowed for the comparison of post-harvest processed oysters to traditional oysters; comparisons were not made between different types of post-harvest processed oysters. Four types of post-harvest processed oysters were included in the study: HHP, irradiated, IQF, and a simulated version of cool pasteurization. Oysters were harvested from Apalachicola, Florida, in September 2010 and transported for processing.

For the sensory study (Otwell et al, 2010), panelists were presented with two separate pairs of oysters (traditional oyster versus one type of PHP oyster) and asked to eat the oysters and choose the oyster they preferred. Following the taste test, panelists rated the acceptability of the oysters using a 9-point hedonic scale on overall likeability, appearance, texture, and flavor. The taste test and acceptability testing were conducted at 7 days and 14 days post-harvest by the same set of panelists. The study was conducted with 90 consumers from

[6]However, safety is still a consideration for shucked oysters because anecdotal evidence suggests that some consumers eat them raw.

Table 3-3. Literature Review on Consumer Response to PHP-Treated Oysters: Sensory Studies

Study	Study Design	Sample Population	Type of PHP Oyster Evaluated	Results
Garrido and Otwell (2007)	Gulf oysters were evaluated by a trained sensory panel.	14 individuals (after 2 weeks of testing, 14 of 20 to 25 panel candidates who demonstrated the best ability to detect and differentiate basic product attributes of oysters were selected for the profiling panel).	PHP (type of processing not specified) and control (traditional, not processed oyster)	PHP and traditional oysters were similar with regard to aroma, basic flavors, and flavors and aftertastes. With regard to appearance, testers noted a noticeable adductor muscle and thick and dark liquor for post-harvest processed oysters. With regard to texture, testers noted the adductor muscle was distinctly firm and the meat slightly firm for post-harvest processed oysters, and for traditional oysters the testers noted slightly firm adductor muscle and meat.
Andrews and Coggins (2004)	Gulf oysters harvested in October were treated and acceptability testing[a] conducted within 5 days of processing.	Consumer panels conducted in Long Beach, California, and Pass Christian and Biloxi, Mississippi (n = 528); 77% male, 73% white; 49% consumed oysters less than once a month.	IQF, cool pasteurized, and HHP, no control	Differences in overall mean acceptability scores were not statistically significant for the different types of post-harvest processed oysters. 77% of panelists said they would consume more raw oysters if free of bacterial pathogens.
Coggins (2004)	Gulf oysters harvested in December/January were treated and evaluated by a trained sensory panel 2 days after processing.	Sensory panel with 4 months of training (number of panelists not specified).	IQF, cool pasteurized, HHP, and control	Evaluated on various attributes of appearance, aroma, flavor, and taste; no significant differences between raw oyster attributes and the post-harvest processed oysters.

(continued)

Table 3-3. Literature Review on Consumer Response to PHP Treated Oysters: Sensory Studies (continued)

Study	Study Design	Sample Population	Type of PHP Oyster Evaluated	Results
Andrews (2003)	Gulf oysters harvested in December/January were treated and acceptability testing[a] conducted within 5 days of processing.	Consumer panels conducted in Long Beach, Mississippi; Gulfport, Mississippi; Biloxi, Mississippi; and Jackson, Mississippi (n = 254); 72% male, 96% white; 71% consumed oysters less than once a month.	IQF, cool pasteurized, and HHP; no control	Overall mean acceptability scores were not statistically significant for the different types of post-harvest processed oysters. Acceptability of the individual sensory qualities measured was similar for each of the three types of treated oysters. post-harvest processed oysters had one or two areas that they scored higher than the others but the differences were not statistically significant.
Andrews, Posadas, and Jahncke (2002)	Gulf oysters harvested in December and early March were irradiated and sensory triangle difference tests[b] conducted within 1 week of processing.	Consumer panels conducted at MSU Coastal Aquaculture Unit Open House, Gulfport, Mississippi (n = 80) and International Boston Seafood Show (n = 66).	Irradiated and control	38% of panelists could detect a difference between the irradiated and the control samples. There was no significant difference observed between irradiated oysters and the control samples ($p < 0.001$).
Otwell and Garrido, reported in Balthrop (2001)	Gulf oysters were frozen and sensory triangle difference tests[b] conducted; frozen oysters were stored for 21 days, and fresh oysters were shucked within 48 hours of harvest.	Consumer panel conducted in Florida (n = 67); 66% male, 81% 18 to 34 years old.	Frozen and control	55% of panelists could detect a difference between fresh and previously frozen oysters. Of the 37 correct responses, 51% found the previously frozen oysters to be more acceptable, while 49% preferred fresh oysters.

(continued)

Table 3-3. Literature Review on Consumer Response to PHP Treated Oysters: Sensory Studies (continued)

Study	Study Design	Sample Population	Type of PHP Oyster Evaluated	Results
Otwell et al. (2010)	Gulf oysters were harvested from Apalachicola, Florida, in September and transported for processing. Panelists were presented with two separate pairs of oysters (control versus one type of PHP oyster) and asked to eat the oysters and choose the oyster they preferred. Following the taste test, panelists rated the acceptability of the oysters.[c] The taste tests and acceptability testing were conducted at 7-day and 14-day post-harvest by the same set of panelists.	Consumer panel conducted in Gainsville, Florida (n = 84 to 90); 51% male, 66% 20 to 40 years old; 43% consume oysters more than once a month.	HHP, irradiated, IQF, a simulated version of cool pasteurization, and control	At 7 days post-harvest, the majority of panelist preferred traditional oysters to post-harvest processed oysters. The initial preference for traditional oysters was statistically significant (at the 95% confidence level) in comparisons with the simulated version of cool pasteurization, HHP, and irradiated oysters. At 14 days post-harvest, there were no statistically significant differences in panelists' preferences for traditional and post-harvest processed oysters. Overall likeability was scored significantly higher for traditional oysters in comparisons with the four types of post-harvest processed oysters tested after 7 days post-harvest (differences were statistically significant at the 95% confidence lever). However, there were no significant differences in overall likeability after 14 days post-harvest. After 7 days post-harvest, appearance was not a significant factor in acceptability except in comparison of traditional oysters with IQF oysters; however, there were significantly higher ratings for acceptable texture and flavor when traditional oysters with most of the four types of post-harvest processed oysters. After 14 days post-harvest, most acceptability ratings were not significantly different when traditional oysters were compared with the four types of post-harvest processed oysters.

[a] Consumers rated oysters on a 0 to 10 scale, with 0 = bad and 10 = excellent on color, texture, flavor, juiciness, odor, saltiness, and overall acceptability.

[b] In a triangle difference test, consumers are presented three oysters in random order; two are alike and one is different. Testers are asked to pick the one they think is the odd sample out of the three.

[c] Consumers rated oysters on a 1 to 9 scale, with 1 = dislike extremely, 5= neither like nor dislike, and 9 = like extremely on appearance, texture, flavor, and overall likeability.

Table 3-4. Literature Review on Consumer Response to PHP-Treated Oysters: Consumer Surveys

Study	Study Design	Sample Population	Type of PHP Oyster Evaluated	Results
Posadas and Andrews (in press)	Telephone survey and personal interviews conducted to evaluate consumer attitudes and preferences toward irradiated raw oysters and their WTP for irradiated raw oysters.	Total of 1,432 respondents: (1) random digit dial (RDD) telephone survey of adults living in Baltimore (n = 610) and Houston (n = 606) Metropolitan Statistical Areas and (2) personal interviews conducted at MSU Coastal Aquaculture Unit Open House, Gulfport, Mississippi (n = 75) and International Boston Seafood Show (n = 141); 43% male, 72% white, 33% were raw oyster consumers.	Irradiated	43% of raw oyster consumers believed that irradiated oysters have the same quality as fresh compared with 22% of nonconsumers. Among raw oyster consumers, 48% were interested in buying irradiated oysters compared with 8% for nonconsumers. Among raw oyster consumers, the WTP for irradiated oysters averaged $6.32 (SD = $2.77) for a dozen oysters at the supermarket.
Morgan, Martin, and Huth (2009)	Web-based contingent behavior analysis; the impact of post-harvest treated oysters was examined by exposing respondents to nontechnical information about the efficacy of various types of PHP treatments to mitigate the risk of illness and then asking respondents how their anticipated oyster consumption would change.	Telephone survey of Florida adults was used to identify oyster consumers with Internet access and obtain baseline data (n = 368); Web-based survey conducted for contingent behavior analysis (n = 79); 94% white, 42% male.	Not specified	Results suggest that consumers do not respond favorably to treated oysters, and charging a price premium for treated oysters has a significant effect on reducing demand.

(continued)

Table 3-4. Literature Review on Consumer Response to PHP-Treated Oysters: Consumer Surveys (continued)

Study	Study Design	Sample Population	Type of PHP Oyster Evaluated	Results
Posadas and Posadas (2004)	Survey of fair attendees, additional information not provided on study methods.	Individuals attending the Jackson County Fair in Pascagoula, Mississippi (n = 511); 49% male, 41% raw oyster consumers.	HHP, cool pasteurized, IQF, heat shocked (HS), and irradiated (WTP estimates only)	Awareness of PHP methods among raw oyster consumers: 24% HHP, 16% pasteurized, 13% IQF, and 10% HS. Interest in purchasing post-harvest processed oysters among raw oyster consumers: 25% full shell, 31% half shell, 36% shucked. Level of interest in purchasing post-harvest processed oysters among raw oyster consumers, 0 to 5 scale, 0 = not interested and 5 = very interested: 1.32 ± 1.89 HHP, 1.37 ± 1.94 pasteurized, 0.94 ± 1.66 IQF, 0.90 ± 1.57 HS. WTP for dozen oysters on the half shell purchased at supermarket among raw oyster consumers who are willing to buy post-harvest processed oysters: $4.45 (SD = 4.21) HHP, $4.00 (SD = 2.66) pasteurized, $4.14 (SD = 4.31) IQF, $3.22 (SD = 2.42) HS, and $3.72 (SD = 3.46) irradiated.
Hanson et al. (2003)	Mail survey stratified by nine Census regions; respondents asked to rate four oyster post-harvest treatment methods to increase their confidence in safety of oysters and their WTP for treated oysters.	U.S. households (n = 1,376); 43% were oyster consumers.	Depuration, ozonation, irradiation, and pressurization	When asked to select the preferred process, 61% chose depuration, 16% chose pressurization, 12% chose ozonation, and 9% chose irradiation. More than 10% of oyster consumers said ozonation, irradiation, and pressurization would decrease their consumption of oysters. Those who had a preference for one of the four methods indicated a mean WTP of $0.30 more per oyster (range = $0 to $9.99), and 36% indicated that they were not willing to pay more (i.e., WTP = $0).

(continued)

Table 3-4. Literature Review on Consumer Response to PHP-Treated Oysters: Consumer Surveys (continued)

Study	Study Design	Sample Population	Type of PHP Oyster Evaluated	Results
Zimet, reported in Balthrop (2001)	Telephone survey of oyster consumers to collect information on consumption patterns and preferences for frozen oysters.	U.S. households with at least one oyster consumer (n = 1,800); 49% male, 15% consume oysters more than once a month.	Frozen	32% of oyster consumers expressed some interest in frozen oysters. 11% indicated a willingness to purchase frozen oysters on the half shell from the supermarket, and 15% indicated a willingness to purchase whole frozen oysters from the supermarket. Of these, 77% were willing to pay at least $5 per dozen for frozen oysters. Respondents with health concerns about eating oysters were significantly more likely to purchase frozen oysters from the supermarket compared with consumers without such concerns; 22% vs. 15% for whole frozen oysters and 17% vs. 11% for frozen oysters on the half shell.

[a] To avoid potential confusion or bias derived from the name of the process, the treatments were described instead of using the technical name for the process. For example, irradiation was described as "a process of exposing oysters to a direct light energy."

the Gainesville, Florida, area. The study findings suggest that panelists were willing to accept the four types of post-harvest processed oysters but preferred traditional oysters to post-harvest processed oysters at 7 days post-harvest; however, panelists were less able to discern differences between PHP and traditional oysters at 14 days post-harvest.

Taking a closer look at the study results, at 7 days post-harvest, panelists preferred traditional oysters compared with post-harvest processed oysters in comparisons with the simulated version of cool pasteurization, HHP, and irradiated oysters (difference was statistically significant at the 95% confidence level). At 14 days post-harvest, there were no statistically significant differences in panelists' preferences for traditional and post-harvest processed oysters.

After 7 days post-harvest, overall likeability was scored significantly higher for traditional oysters in comparisons with the four types of post-harvest processed oysters (differences were statistically significant at the 95% confidence level). However, there were no statistically significant differences in overall likeability after 14 days post-harvest. After 7 days post-harvest, appearance was not a statistically significant factor in acceptability except in comparison of traditional oysters with IQF oysters; however, there were significantly higher ratings for acceptable texture and flavor for traditional oysters compared with most of the four types of post-harvest processed oysters.

After 14 days post-harvest, most acceptability ratings were not significantly different when traditional oysters were compared with the four types of post-harvest processed oysters.

For the WTP study, Dr. Huth and colleagues conducted four experimental auctions with 30 participants each, for a total of 120 participants. For each round of the experimental auction, traditional oysters were compared with the four different types of post-harvest processed oysters with increasing information and taste tests. The final report is not available, but based on findings presented at the ISSC Vibrio Management Committee Meeting on January 11, 2011, the study found substantial reductions in willingness to pay for post-harvest processed oysters (Huth, 2011).

The sensory studies that we reviewed suggest that consumers of raw oysters and individuals on trained sensory panels could not detect differences between traditional and post-harvest processed oysters, with the exception of previously frozen oysters.

We identified six other sensory studies that assessed consumer response to post-harvest processed oysters. These studies included taste tests with consumers, acceptability testing with consumers, and sensory tests using trained sensory panels. Four of the studies compared post-harvest processed oysters to traditional oysters (i.e., a control), and two studies compared different types of post-harvest processed oysters. For studies that compared post-harvest processed oysters to traditional oysters, the results suggest that consumers of raw oysters and individuals on trained sensory panels could not detect differences between traditional and post-harvest processed oysters. The exception to this was a study that compared previously frozen oysters with traditional oysters in which 55% of panelists could detect a difference; however, with regard to acceptability, there was no clear preference between previously frozen and fresh oysters (Balthrop, 2001). The individual study findings are summarized below.

In addition to the taste test sponsored by ISSC, we reviewed two additional taste test studies. The studies used a sensory triangle difference test, in which consumers are presented three oysters in random order—two are alike and one is different. Testers are asked to pick the one they think is the odd sample out of the three. In a taste test conducted by Andrews, Posandas, and Jahncke (2002) with 146 raw oyster consumers, 38% of panelists could detect a difference between irradiated oysters and the control samples (fresh oysters). These results suggest that there was no significant difference observed between the irradiated oysters and the control samples ($p < 0.001$). In a taste test conducted by Otwell and Garrido at the University of Florida (Balthrop, 2001) with 67 raw oyster consumers, 55% of panelists could detect a difference between previously frozen oysters and the control samples (p value not provided), suggesting that consumers can distinguish fresh oysters from similar previously frozen oysters. However, there was no clear preference between previously frozen and fresh oysters. Of the 37 correct responses, 51% found the previously frozen oysters to be more acceptable, while 49% preferred the fresh oysters.

Andrews (2003) and Andrews and Coggins (2004) conducted acceptability testing of IQF, pasteurized (same as cool pasteurization), and HHP oysters. The studies did not include control samples. Panelists rated oysters on a 0 to 10 scale, with

0 indicating bad and 10 indicating excellent on the following factors: color, texture, flavor, juiciness, odor, saltiness, and overall acceptability. For both studies, the differences in the overall mean acceptability scores for the three types of treated oysters were not significantly different. The Andrews (2003) study reported that the acceptability of the individual sensory qualities measured was similar for each of the three types of post-harvest processed oysters. Post-harvest processed oysters had one or two areas on which they scored higher than the others, but the difference was not statistically significant.

Coggins (2004) conducted sensory testing of IQF, cool pasteurized, HHP, and traditional oysters using a trained sensory panel. The oysters were evaluated on various attributes of appearance, aroma, flavor, and taste. The study found no significant differences between traditional oyster attributes and post-harvest processed oysters. Garrido and Otwell (2007) conducted sensory testing of PHP (type of processing not specified) and traditional oysters using a trained sensory panel. Panelists found the PHP and traditional oysters similar with regard to aroma, basic flavors, and flavors and aftertaste; however, differences were noted for appearance and texture with regard to the adductor muscle for post-harvest processed oysters.

The consumer surveys that we reviewed suggest that most consumers are not willing to buy post-harvest processed oysters, and of those who are, they are willing to pay about the same amount as they would for traditional oysters.

Several surveys have been conducted to assess consumer response to PHP and their WTP for treated oysters. A limitation of these studies is that consumers did not have the opportunity to view or taste the treated oysters. The findings from these surveys suggest that most consumers are not willing to buy post-harvest processed oysters, and of those who are, they are willing to pay about the same amount as they would for traditional oysters. Although a few of these surveys collected information on respondents' attitudes toward post-harvest processed oysters, analyses were not conducted to assess the attitudes of respondents who indicated that they were not willing to buy post-harvest processed oysters. Thus, information is not available to assess reasons why respondents were not willing to buy post-harvest processed oysters. The individual study findings are summarized below.

In a study conducted by Posadas and Andrews (in press), 43% of raw oyster consumers believed that irradiated oysters had the same quality as fresh, and 48% of raw oyster consumers

were interested in buying irradiated oysters. Only 17% of all respondents indicated a WTP for irradiated oysters. For raw oyster consumers, the average WTP was $6.32 (SD = $2.77) for a dozen oysters at the supermarket.

A study conducted by Dr. David Zimet (Balthrop, 2001) found that 32% of oyster consumers expressed some interest in frozen oysters. Eleven percent indicated a willingness to purchase frozen oysters on the half shell from the supermarket, and 15% indicated a willingness to purchase whole frozen oysters in the supermarket. Of these, 77% were willing to pay at least $5 per dozen for frozen oysters purchased in the supermarket.

Posadas and Posadas (2004) surveyed raw oyster consumers on their response to HHP, cool pasteurized, IQF, heat shocked, and irradiated oysters. Awareness of PHP methods was low, ranging from 10 to 24% depending on the type of processing. The percentage of respondents expressing interest in purchasing post-harvest processed oysters was 25% for full shell, 31% for half shell, and 36% for shucked. Among raw oyster consumers willing to buy post-harvest processed oysters, the mean WTP for a dozen oysters in the half shelf purchased at the supermarket was between $3.22 and $4.45 depending on the type of PHP oyster.

As part of a study conducted by Hanson et al. (2003) consumer response to four processes used to treat oysters (depuration, ozonation, irradiation, and pressurization) was assessed. To avoid potential confusion or bias derived from the name of the process, the treatments were described instead of using the technical name for the process. For example, irradiation was described as "a process of exposing oysters to a direct light energy." When asked to select the preferred treatment process, 61% chose depuration, 16% chose pressurization, 12% chose ozonation, and 9% chose irradiation. More than 10% of oyster consumers reported that ozonation, irradiation, and pressurization would decrease their consumption of oysters. Respondents with a preference for one of the four treatment processes indicated a mean WTP of $0.30 more per oyster (range = $0 to $9.99), and 36% indicated that they were not willing to pay more (i.e., WTP = $0).

Finally, Morgan, Martin, and Huth (2009) conducted a Web-based contingent behavior study to examine the effect of information on oyster demand. The impact of post-harvest processed oysters was examined by exposing respondents to nontechnical information about the efficacy of various types of post-harvest processes to mitigate the risk of illness and then asking respondents how their anticipated oyster consumption would change. The study findings suggest that consumers would not respond favorably to processed oysters and that charging a price premium would have a significant effect on reducing demand.

3.3.3 Potential Restaurant Manager Reaction to Post-harvest Processing

Restaurant managers' reactions to processed oysters will depend on product liability concerns, quality issues, and the practicality of serving processed oysters.

In addition to consumer perceptions regarding PHP, the effects of PHP on oyster demand depend on whether and where oysters are available as a result of processing. A restaurant or food service operation's decision to carry oysters is and will continue to be affected by whether the oysters are processed. Their specific reactions depend on the following:

- whether they are concerned about safety from a product liability viewpoint,
- whether they have other quality concerns about the product,
- whether it is feasible from a practical standpoint for the establishment to offer post-harvest processed oysters (i.e., because of shelf life, storage requirements, and the need for a shucker on staff), and
- the cost of post-harvest processed oysters relative to traditional oysters and the effects of the increased cost on menu prices.

Restaurant or food service operators' responses to each of these factors affect whether they will begin to offer or discontinue offering oysters as a result of PHP.

To learn more about the experiences and perceptions of individual restaurant managers and owners regarding treated oysters, we interviewed nine restaurants during September through November 2010. Appendix A provides a copy of the interview guide.

We purposively selected restaurants to interview that serve Gulf oysters. We interviewed owners or managers of eight

restaurants that are independently owned and one that is part of a local chain. We interviewed restaurants in the following locations: Sarasota, Florida (two); Birmingham, Alabama (two); Houston, Texas (one); Dallas, Texas (two); Atlanta, Georgia (one); and St. Louis, Missouri (one). Eight of the nine restaurants obtain most of their sales from seafood rather than nonseafood items. Oyster purchases ranged from 2 boxes per week to 60 sacks per week. Respondents were asked to describe their experiences prior to the Deepwater Horizon oil spill.

The restaurants interviewed serve raw Gulf oysters year round. When serving raw Gulf oysters on the half shell during the summer, five serve only traditional oysters, two serve traditional and frozen, one serves traditional and HHP, and one serves HHP only. One restaurant used to serve cool pasteurized oysters but stopped serving them because of poor taste. Trends in raw Gulf oyster sales over the past 5 years varied. Six restaurants reported a slight or significant increase in sales, two reported no change, and one reported a slight decrease in sales.

We asked respondents how their restaurant would respond if FDA required PHP of Gulf oysters harvested in the summer and intended for half-shell consumption. Responses varied as summarized below:

- One respondent said price would be a concern and the ultimate deciding factor in the decision.
- Two respondents would serve only Gulf oysters harvested within state, if the state would allow intrastate sales of traditional oysters.
- One respondent would serve traditional, intrastate oysters, frozen Gulf oysters, and/or oysters from other regions of the country.
- One respondent would serve oysters from other regions of the country.
- One respondent would continue serving frozen oysters or oysters from other regions of the country.
- The two respondents who serve HHP Gulf oysters would continue doing so.
- One respondent would stop serving oysters.

With regard to the price of treated oysters, respondents who would consider serving or currently serve treated oysters said that they would charge up to $1.00 per dozen more, that they would charge the same to keep prices the same for their customers, or that they charged up to 25% more for treated oysters.

We asked respondents to provide their opinion on consumers' responses to processed Gulf oysters with regard to sensory changes, increased safety, possible price changes, and overall response. Respondents' opinions varied on how they think consumers would respond to the sensory changes of post-harvest processed oysters. Several respondents believed most consumers would not notice the difference, while others believed most consumers would respond poorly. For respondents with experience selling post-harvest processed oysters, they believed consumer response would depend on the type of process. One respondent does not like the taste of cool pasteurized oysters, one respondent said freezing changes the taste and texture, and one respondent believed HHP does not change the oysters' sensory characteristics.

Respondents also had mixed opinions on how consumers would respond to the increased safety of post-harvest processed oysters. Some respondents believed consumers would appreciate the increased safety of post-harvest processed oysters, while some believed that consumers are more concerned about the sensory characteristics of oysters than safety. With regard to possible price changes, some respondents believed consumers would respond poorly to a price increase, one respondent believed consumers would be willing to pay more for the increased safety of post-harvest processed oysters, and some respondents said it was not an issue because they would not charge their customers a price premium for post-harvest processed oysters.

The findings from the interviews with restaurant managers and owners suggest that consumer response to treated Gulf oysters will vary and will depend on factors such as the type of post-harvest process used and consumer characteristics (e.g., the frequency with which raw oysters are consumed).

Overall, when asked how their consumers have responded or would respond to post-harvest processed oysters, four respondents believed consumers would respond favorably, four respondents believed consumers would respond unfavorably, and one respondent said it depends on the customer.

The variation in respondents' answers suggests that many factors would determine consumer response to post-harvest processed Gulf oysters. These factors include the type of post-harvest process used and the characteristics of the consumer. Based on the limited number of interviews we conducted, it appears the extent of sensory change may depend on the type of process used. The interview findings suggest that consumers who are "die hard" consumers of traditional oysters are likely to be opposed to eating post-harvest processed oysters, whereas other oyster eaters may not notice the difference.

3.3.4 Response to the 2003 Ban by California on Sales of Raw Gulf Oysters during the Summer

In April 2003, California enacted a statewide ban on the sale of raw oysters harvested from the Gulf of Mexico from April through October each year, unless they are processed to reduce levels of *Vibrio vulnificus* to nondetectable levels. Since the ban, no deaths have been attributed to *Vibrio vulnificus* in California. By comparison, between 1991 and 2001, 40 people died in California from the infection (Taylor, 2009).

To collect information on restaurant and grocery store responses to the California ban, we contacted representatives from the following organizations:[1]

- California Grocers Association
- California Restaurant Association
- Food Marketing Institute
- University of California, Davis
- National Fisheries Institute
- Louisiana Seafood Promotion and Marketing Board
- *Seafood Business* magazine
- California Fisheries Coalition

[1] We were unsuccessful in talking with a representative from the California Department of Public Health.

However, none of these organizations were aware of any studies or data collection that had been conducted to evaluate the market response to the California ban.

Based on our interviews with the companies that process and sell post-harvest processed oysters, sales of post-harvest processed oysters to buyers in California increased in the summer following the ban. However, it is not known to what extent restaurants and grocery stores began purchasing oysters from other parts of the country or completely stopped selling raw Gulf oysters during the summer.

Fiona Robinson (2010), the Associate Publisher and Editor of *Seafood Business* magazine, was not aware of any studies or data on industry response to the ban). When asked to comment on response to the ban, she said that she believes some restaurants started selling post-harvest processed oysters because of liability concerns, and some restaurants started buying oysters from other parts of the country (e.g., East Coast or Washington State). She does not think many businesses completely stopped selling oysters if oysters were already a menu option.

4 Costs and Feasibility of Post-harvest Processing

In this section, following a discussion of key assumptions used in the analysis, we present estimates of the costs of installing and operating PHP for half-shell oysters harvested in the Gulf. Because of the benefits obtained from applying PHP to shucked oysters, we also present estimates of the costs or cost savings associated with shucked oysters. We then present the results of three phases of the feasibility analysis—the availability of existing PHP capacity in the Gulf, the feasibility of toll processing using existing or potential capacity, and the feasibility of using central PHP facilities for PHP of Gulf oysters.

To conduct the feasibility analysis and develop estimates of the costs of installing and operating PHP equipment, we investigated the following treatment options:

- HHP
- cool pasteurization
- irradiation
- IQF with extended storage
- high-salinity treatment (through relaying)

Among these options, we determined that the first three options are currently feasible for some portion of the summer Gulf oyster industry. In contrast, IQF is not feasible for summer-harvested oysters, and high-salinity treatment is too new to determine its feasibility (see discussion in Section 3). Switching from half-shell to shucked-only production is not a feasible alternative response for oyster operations because of

the substantially lower yields, resulting in negative returns, associated with shucking summer-harvested oysters due to spawning. The Gulf states could decide to respond to requirements for PHP by closing harvest areas; however, for the purposes of this analysis, we assumed that the states would not exercise this option so that the feasibility analysis addresses the maximum possible requirements for PHP.[1]

Note that some of the data provided in this report are aggregated to protect the confidentiality of proprietary information.

To develop the cost estimates, we obtained detailed information from the following organizations:

- Motivatit Seafoods (site visit)—HHP
- Joey's Oysters (teleconference)—HHP
- Prestige Oysters (site visit)—HHP (recently installed equipment not yet operating at the time of visit)
- Avure Technologies, Inc. (teleconference)—equipment manufacturer for HHP
- AmeriPure Oysters (site visit)—cool pasteurization process
- Food Technology Services, Inc. (FTSI) (teleconference)—irradiation facility providing services on a toll basis

We used the information from Motivatit Seafoods, Joey's Oysters, Prestige Oysters, and Avure to develop estimates of the initial purchase and installation and annual operating costs for HHP. AmeriPure is the only source of information on the costs associated with the cool pasteurization process, so our estimates are based on the information provided by the company. FTSI provided information on toll processing costs that need to be factored in with the costs of transportation and other handling charges associated with using irradiation. In addition, we describe logistical issues regarding use of irradiation because the process is designed for treatment of boxed products on pallets.

[1] All of the Gulf state agencies we spoke with said they would consider the option of harvest area closures but primarily in response to the state not meeting the 60% illness reduction goal for *Vibrio vulnificus* rather than specifically in response to requirements for PHP. Some state agencies are concerned about policing whether oysters harvested from state waters (many of which close in the summer under current practices) have undergone a PHP process. This concern would make them more inclined to close harvest areas. However, all the agencies said they could not give a definitive answer regarding whether the state would close harvest areas.

We also conducted brief discussions with the following operations that operate validated IQF processes:

- 13 Mile (Tommy Ward Seafood), Florida
- Crystal Sea's Seafood, Mississippi
- Hillman Shrimp & Oyster, Texas (declined to participate in a discussion)
- Jeri's Seafood, Texas
- Leavin's Seafood, Florida
- R & A Oyster Company, Alabama
- Webb's Seafood, Florida
- Wilson's Oysters, Louisiana

In addition to these operations, we also discussed use of IQF with Motivatit Seafoods, which operates IQF equipment in addition to HHP, and Prestige Oysters, which has installed but had not yet operated IQF equipment.

4.1 KEY ASSUMPTIONS REGARDING COSTS AND FEASIBILITY

To conduct the cost and feasibility analysis, we developed assumptions and estimates needed for the analysis. We considered two scenarios regarding use of PHP:

- **Scenario 1**: 2,000 hours of PHP processing per year (equivalent to 8 hours of processing time per shift with one shift per day and operating 250 days per year)
- **Scenario 2**: 4,800 hours of PHP processing per year (equivalent to 8 hours of processing time per shift with two shifts per day and operating 300 days per year)

In both scenarios, the work shift would be longer than 8 hours to accommodate set up prior to operation and cleanup time following operation. Use of these typical scenarios facilitates the calculations for the model, although specific processors might follow a somewhat different schedule such as longer shifts operating fewer days per year.

Assumptions used in the analysis are based on information provided by oyster processors during the industry interviews. *These assumptions may be further refined based on feedback provided by FDA or industry.*

For calculations involving oyster volumes, we applied the following assumptions:

- 250 oysters per 100-pound sack at harvest (actual numbers may range from 180 to 300 depending on harvest location and season)
- 7 pounds of oyster meat per 100-pound sack of oysters average over the course of the year (actual pounds may range from 3.5 to 10 pounds per sack depending on harvest location and season), which equates to approximately 36 oysters per meat-weight pound
- 4 pounds of oyster meat per 100-pound sack of oysters in the summer (actual pounds may range from 3.5 to 5 pounds per sack), which equates to approximately 62 oysters per meat-weight pound
- 60% of Gulf harvest oysters are sold for half-shell use and 40% are sold for shucking over the course of a year

In developing the cost estimates associated with cool pasteurization and HHP, we applied a few general assumptions regarding costs, yields, and labor requirements across the treatment options. These assumptions are as follows:

Banding costs for half-shell oysters, yield increases for shucked oysters, and labor savings for shucking oysters augment the costs of PHP capital equipment and operating costs.

- **Banding costs for half-shell oysters.** PHP processes tend to cause treated oysters to gap; thus, processors apply rubber bands or shrink-wrapped plastic to oysters intended for the half shell. These bands or shrink wraps prevent oysters from losing their liquor and help preserve shelf-life. None of the PHP processors we spoke with use an automated process to apply bands to oysters, although several have investigated developing the needed machinery. To estimate costs of applying bands, we included the cost of the band or wrap and the cost to apply them. Bands or wraps range in cost from $0.005 to $0.015 per oyster with no noted differences between rubber bands or plastic wraps. The labor cost to apply bands or wraps on a piece meal or hourly basis ranges from $0.010 to $0.033 per oyster. The resulting cost per half-shell oyster ranges from 1.5 to 3.8 cents. We used 3.0 cents per half-shell oyster as a typical estimate in the calculations.
- **Yield increases for shucked oysters.** PHP processes separate the oyster muscle from the shell without tearing the oyster; thus, post-harvest processed oysters tend to have higher yields compared with traditional

oysters.[2] Typical yields per 100-pound sack of oysters range from 3.5 to 5 pounds in the summer and 7.5 to 10 pounds in the winter, depending on the size of the oysters and whether they have been through a PHP process. Based on information provided by oyster processors, PHP increases yields by 10 to 25% for the HHP and cool pasteurization processes.[3] If we assume an average increase of 1 pound per sack at a pre-oil spill price of $7.50 meat-weight pound, PHP increases the revenue received by $7.50 per sack or the equivalent of 3.0 cents per oyster.

- **Shucking labor savings.** Because HHP processes cause unbanded oysters to open slightly, they tend to be much easier to shuck relative to traditional oysters. The result is that HHP oysters can be shucked faster and require less skill than traditional oysters. Based on information provided by HHP processors and Avure, shucking labor time is reduced by 40 to 45%. If it takes 45 minutes to shuck a sack of traditional oysters and 25 minutes to shuck a sack of HHP oysters, the process reduces shucking time by 20 minutes per sack. At an average hourly rate of $10.00 and 250 oysters per sack, HHP results in a savings of 1.3 cents in shucking labor per shucked oyster.

We used these assumptions in developing the cost estimates presented in Section 4.2.

4.2 COSTS OF POST-HARVEST TREATMENT PROCESSES

Cost estimates were developed for

- cool pasteurization,
- HHP, and
- irradiation.

Each of the PHP methods is associated with increased capital equipment, labor, or energy requirements and potential revenue changes due to changes in the type or nature of the product sold. For each PHP method, we used the information collected during the industry interviews to develop typical estimates of capital equipment costs (and life of capital equipment) and costs of labor, energy, and materials for

[2] Although oyster processors that operate PHP equipment claim that based on their experience, shucked post-harvest processed oysters have higher yields compared with shucked traditional oysters, we note that others in the oyster industry believe that yield increases are minimal or nonexistent or that shucked post-harvest processed oysters have poorer quality compared with shucked traditional oysters.

[3] Avure Technologies stated that yield increases for the HHP process were in the range of 20 to 50% with an average of 30%. However, this estimate is higher than the estimates provided by the HHP processors.

representative size operations. Capital equipment and other initial costs are annualized and added to annual operating costs to develop a total annual cost estimate for each PHP process. We present the resulting estimates for each of the three processes. In Section 5, we use these cost estimates to develop a total annual industry compliance cost estimate associated with PHP requirements in the Gulf.

Additional costs beyond those explicitly identified below might also be incurred. Specifically, insurance coverage for additional plant space and equipment may be a significant expense, especially in areas prone to severe weather and flooding. In addition, ongoing testing for verification of the process to ensure reduction of *Vibrio vulnificus* to nondetectable levels will be required. Furthermore, if processors are unable to install processing equipment at their facilities and instead rely on toll processing, they will incur additional costs for refrigerated shipping to (and from) the toll processing facility.[4] These costs would include either paying for trucking services or purchasing and operating a refrigerated truck.

For cool pasteurization and HHP, the time required to install and begin operating the processes would need to allow for activities such as the following:

- developing plans for expanding the plant or altering the plant layout;
- obtaining building permits;
- securing financing for purchasing equipment;
- constructing the expanded facility;
- modifying electrical, natural gas, and water hookups;
- purchasing and installing equipment;
- validating and verifying the process;
- training workers on operation and maintenance of the equipment;
- updating the operation's HACCP plan to address PHP;
- updating record-keeping systems; and
- updating product labeling and notifying buyers.

[4] At the current time, the only available toll processing facility in the Gulf is the irradiation facility in Mulberry, Florida, which has not yet been used commercially for oysters.

RTI's estimate of the time required to complete these activities is a minimum of 2 years. However, this estimate assumes that the equipment manufacturers could fulfill all orders as they are received and have sufficient staff available to support the delivery and installation of the equipment and the staff training on use of the equipment. It is currently unknown whether the equipment manufacturers could satisfy these needs.

4.2.1 Cool Pasteurization[5]

For the cool pasteurization process, estimated costs are between 4 and 5 cents per half-shell oyster and cost *savings* are about 1 cent per shucked oyster (if the process is applied to oysters intended for shucking).

Table 4-1 provides estimates of throughput, total costs, and per-unit costs associated with two process sizes for the cool pasteurization process based on a 2,080-hour annual operating schedule (similar to Scenario 1). Assuming that the process is applied to both half-shell and shucked oysters, the resulting per-oyster PHP cost, including both amortized capital equipment costs and annual operating costs, is 3.3 cents per half-shell oyster and −1.2 cents per shucked oyster for the large process and 3.7 cents per half-shell oyster and −0.8 cents per shucked oyster for the small process (not including transportation costs if a toll processing facility is used). Negative cost values for shucked oysters means that processors incur "savings" resulting from increased yields for shucked oysters.

The small process can handle 18,000 sacks of oysters per year and is similar to the original commercial process developed by AmeriPure. The large process can handle 145,600 sacks per year using holding tanks with capacity of 7,500 gallons (hot tank) and 5,500 gallons (cold tank) and is similar to the current process used by AmeriPure.[6] Estimates of the costs of plant expansion were calculated by multiplying $150 per square foot by the square footage required for the cool pasteurization equipment (200 square feet for the small process and 1,750 square feet for the large process). For both the small and large processes, capital equipment and installation costs were estimated by applying a net inflation factor of 1.31 obtained

[5] The information presented in this section is based on data provided by AmeriPure Oysters to RTI during a site visit to AmeriPure's facility in Franklin, Louisiana, on July 8, 2010. AmeriPure reviewed RTI's initial estimates and provided revisions on November 24, 2010.

[6] AmeriPure Oysters is in the process of building a new, larger facility in Myrtle Grove, Louisiana, which will replace the Franklin, Louisiana, facility. When the new facility is operational, the facility in Franklin, Louisiana, will be put up for sale.

Table 4-1. Throughput Assumptions and PHP Costs for the Cool Pasteurization Treatment Process: 2,080 Operating Hours per Year
Costs include the annualized plant expansion and equipment costs and the annual operating costs.

	Small Process	Large Process
Annual throughput assumptions		
Half-shell oysters	2,700,000	21,840,000
Shucked oysters	1,800,000	14,560,000
Total oysters	4,500,000	36,400,000
Total shell-weight pounds	1,800,000	14,560,000
Total sacks	18,000	145,600
Total cost estimates		
Total plant expansion and capital equipment costs	$74,740	$386,245
Total annual operating costs, including banding costs and yield increases for shucked oysters	$85,075	$555,096
Per-unit cost estimates		
Per half-shell oyster	$0.052	$0.049
Per shucked oyster	−$0.008	−$0.011
Per sack	$7.00	$6.25

Assumptions:

- Each 100-pound sack holds 250 oysters.
- 60% of oysters are sold to the half-shell market and 40% are sold to the shucked market.
- Half-shell oysters incur banding costs of $0.015 per oyster.
- Shucked oysters have labor savings of $0.03 per oyster.
- Plant expansion has a 20-year life and equipment has a 20-year life.
- Interest rates for bank loans to processors are 7%.

from the Bureau of Labor Statistics for the period 1999 to 2009 (2010 is not yet available) to original cost estimates provided by AmeriPure in 1999. Capital equipment requirements for cool pasteurization include

- a boiler,
- a chilling and condensing unit,
- a computer monitored hot and cold exchange unit,
- holding tanks (7,500 gallons for the hot water tank and 5,500 gallons for the cold water tank),
- conveyers,

- hoists for lifting oysters in and out of water tanks,
- an ultraviolet water purification system,
- stainless steel racks, and
- delivery and installation including plumbing and electrical hookups.

Capital equipment costs (including installation) and plant expansion costs were amortized assuming a 20-year life and 7% interest rate.

Current estimates for operating costs—water, electricity, natural gas, labor, replacement parts, and maintenance—were added to banding costs and adjusted for shucking labor savings to develop total annual operating costs. In addition, a licensing fee of $0.0125 per oyster was included. However, when the patents on the process expire in approximately 5 years, the licensing fee will likely no longer apply.

4.2.2 High Hydrostatic Pressure Processing[7]

For HHP, estimated costs are between 4 and 7 cents per half-shell oyster and cost *savings* of 0 to 3 cents per shucked oyster (if the process is applied to oysters intended for shucking).

Table 4-2 provides estimates of throughput, total costs, and per-unit costs associated with four process sizes for HHP based on a 2,000-hour annual operating schedule (Scenario 1), and Table 4-3 provides estimates based on a 4,800-hour annual operating schedule (Scenario 2). Estimates were based on the following machinery sizes as provided by Avure, the equipment manufacturer:

- 100-liter horizontal machine operating at 11 cycles per hour with 120 shell-weight pounds per cycle (requiring space of 12 by 12 feet)
- 320-liter vertical machine operating at 12 cycles per hour with 450 shell-weight pounds per cycle (requiring space of 30 by 20 feet)
- 350-liter horizontal machine operating 12 cycles per hour with 500 shell-weight pounds per cycle (requiring space of 50 by 20 feet)

[7] The information presented in this section is based on data provided to RTI by Avure Technologies during a teleconference on August 4, 2010, and from several follow-up e-mails; a site visit to Motivatit Seafoods facility in Houma, Louisiana, on July 9, 2010; a site visit to Prestige Oysters facility in San Leon, Texas, on August 9, 2010; and a teleconference with Joey's Oysters in Amite, Louisiana, on July 12, 2010.

Table 4-2. Throughput Assumptions and PHP Costs for the HHP Process: 2,000 Operating Hours per Year

Costs include the annualized plant expansion and equipment costs and the annual operating costs.

	100 L Horizontal	320 L Vertical	350 L Horizontal	687 L Horizontal
Annual throughput assumptions				
Half-shell oysters	3,960,000	16,200,000	18,000,000	21,000,000
Shucked oysters	2,640,000	10,800,000	12,000,000	14,000,000
Total oysters	6,600,000	27,000,000	30,000,000	35,000,000
Total shell-weight pounds	2,640,000	10,800,000	12,000,000	14,000,000
Total sacks	26,400	108,000	120,000	140,000
Total cost estimates				
Total plant expansion and capital equipment costs	$1,280,000	$2,050,000	$2,406,250	$3,110,000
Total annual operating costs, including banding costs and yield increases for shucked oysters	$270,662	$637,877	$698,124	$886,320
Per-unit cost estimates				
Per half-shell oyster	$0.070	$0.053	$0.052	$0.054
Per shucked oyster	−$0.003	−$0.020	−$0.021	−$0.019
Per sack	$10.25	$5.91	$5.82	$6.19

Assumptions:

- Each 100-pound sack holds 250 oysters.
- 60% of oysters are sold to the half-shell market and 40% are sold to the shucked market.
- Half-shell oysters incur banding costs of $0.03 per oyster.
- Shucked oysters have labor savings of $0.03 per oyster and increased yields equivalent to $0.013 per oyster.
- Plant expansion has a 20-year life and equipment has a 10-year life.
- Interest rates for bank loans to processors are 7%.

  - 687-liter horizontal machine operating 10 cycles per hour and with 700 shell-weight pounds per cycle (requiring space of 40 by 30 feet)

Assuming the same processing time for half-shell and shucked oysters, the resulting per-oyster PHP costs, including both amortized capital equipment costs and annual operating costs, range from 5.3 to 7.0 cents per half-shell oyster and −1.9 to 0.0 cents per shucked oyster based on 2,000 operating hours per year and from 4.2 to 5.0 cents per half-shell oyster and −2.3 to −3.1 cents per shucked oyster based on 4,800 operating hours per year (not including transportation costs if a toll processing facility is used).[8] A negative cost value for shucked oysters means that processors incur "savings" resulting from increased yields for shucked oysters and reduced labor requirements for shucking oysters.

[8] Anecdotal information suggests that some processors may process oysters intended for shucking for a shorter process than half-shell oysters to facilitate the shucking process rather than to reduce *Vibrio vulnificus* to nondetectable levels.

Table 4-3. Throughput Assumptions and PHP Costs for the HHP Process: 4,800 Operating Hours per Year
Costs include the annualized plant expansion and equipment costs and the annual operating costs.

	100 L Horizontal	320 L Vertical	350 L Horizontal	687 L Horizontal
Annual throughput assumptions				
Half-shell oysters	15,840,000	38,880,000	43,200,000	50,400,000
Shucked oysters	6,336,000	25,920,000	28,800,000	33,600,000
Total oysters	22,176,000	64,800,000	72,000,000	84,000,000
Total shell-weight pounds	8,870,400	25,920,000	28,800,000	33,600,000
Total sacks	88,704	259,200	288,000	336,000
Total cost estimates				
Total plant expansion and capital equipment costs	$1,280,000	$2,050,000	$2,406,250	$3,110,000
Total annual operating costs, including banding costs and yield increases for shucked oysters	$330,854	$830,117	$993,324	$1,062,320
Per-unit cost estimates				
Per half-shell oyster	$0.050	$0.042	$0.043	$0.042
Per shucked oyster	−$0.023	−$0.031	−$0.030	−$0.031
Per sack	$5.22	$3.20	$3.45	$3.16

Assumptions:

- Each 100-pound sack holds 250 oysters.
- 60% of oysters are sold to the half-shell market and 40% are sold to the shucked market.
- Half-shell oysters incur banding costs of $0.03 per oyster.
- Shucked oysters have labor savings of $0.03 per oyster and increased yields equivalent to $0.013 per oyster.
- Plant expansion has a 20-year life and equipment has a 10-year life.
- Interest rates for bank loans to processors are 7%.

Capital equipment requirements for HHP include

- HHP unit and enclosure,
- chiller
- compressor,
- overhead rail system,
- conveyers,
- hoists, and
- delivery and installation costs including electrical hookups.

Licensing fees for HHP are built into the capital equipment costs and, thus, are not separately incurred on a per-oyster basis. Plant expansion costs were estimated assuming the minimum required square footage would be twice the footprint of the HHP equipment. However, the 320 L vertical system requires 23 feet of vertical clearance, which would be difficult in many facilities, in contrast to the horizontal system, which is 6 to 7 feet in height. Thus, plant expansion costs may be higher for installing a vertical process.

Avure provided RTI with estimates of the base equipment costs; additional costs for installation, rail system, conveyors, and building expansion; and operation costs per shellweight pound including labor, electricity, water, building expansion, conveyors, and depreciation costs (using a straight line method). To provide consistency in estimating the costs of plant expansion per square foot and amortizing costs using a 7% interest rate, we decomposed the per-pound operation costs provided by Avure and then reconstructed the plant expansion, installation, and annual per-oyster costs of HHP. We estimated plant expansion costs by multiplying $150 per square foot times twice the square footage requirements provided by Avure. Capital equipment costs were included as provided by Avure. We estimated additional equipment and installation costs assuming that the costs are 10% of capital equipment costs based on detailed information provided by Joey's Oysters (215 L machine) and Prestige Oysters (350 L machine). Per-oyster operating costs were calculated by subtracting our estimate of the portion of Avure's per-oyster operating costs that are attributable to plant expansion, capital equipment, and installation and adding back our annualized estimate of each of these portions of costs assuming a 20-year life for plant expansion, 10-year life for capital equipment and installation, and a 7% interest rate.[9] We then adjusted the per-oyster operating costs to account for banding costs for half-shell oysters and shucking labor savings and increased yields for shucked oysters using the assumptions detailed in Section 4.1.

[9] We estimated the portion of Avure's per-oyster costs that are attributable to plant expansion, capital equipment, and installation by calculating the annual costs of each assuming a straight-line depreciation method and 20-year life for plant expansion and installation (these are grouped in Avure's data) and 10-year life for capital equipment and dividing the result by the number of oysters processed each year.

Following these calculations, we compared the resulting cost estimates to cost estimates calculated using detailed information provided by Joey's Oysters and Prestige Oysters based on their recent experience installing HHP processes. The estimates based on the data from Joey's Oysters and Prestige Oysters were somewhat higher than but generally similar to the estimates provided by Avure. The cause of the differences is unknown but could be due to a variety of factors including differences in the wages and energy prices, imprecision in the method we used to deconstruct Avure's cost estimates, or differences in assumptions used.

4.2.3 Irradiation[10]

For irradiation, the estimated cost is about 6 cents per half-shell oyster, not including refrigerated transportation costs to the irradiation facility.

FTSI currently operates an irradiation facility in Mulberry, Florida, which could provide PHP services for half-shell oysters. Although the process could, in theory, be applied to shucked oysters, there are no advantages related to shucked oyster yields or shucking labor as there are for the other process. The facility operates on a toll processing basis and would charge 7 cents per pound. FTSI estimates there are 3.8 oysters per pound, which would work out to be less than 2 cents per oyster for irradiation processing. However, based on the assumptions used in this report of 2.5 half-shell oysters per pound (250 oysters per 100-pound sack), the cost would be 2.8 cents per oyster. As with the other processes, irradiated oysters would require banding. Thus, the total cost per oyster would be 5.8 cents per oyster.

To use irradiation services, oyster processors would wash, band, and box half-shell oysters into wholesale or retail packaging. FTSI would irradiate the entire pallet of boxed oysters as one unit with processing time of less than 1 hour. One issue of concern is that products generally cannot be labeled as irradiated prior to actual application of the process, which would imply that the pallet of boxes would need to be broken down so that the irradiation label could be applied to each box in the pallet. However, FDA has written a letter (dated December 30, 2009) to the Florida Department of Agriculture and Consumer Services stating that FDA will consider allowing shipments of oysters that are prelabeled as irradiated from a

[10] The information presented in this section is based on data provided by FTSI in Mulberry, Florida, during a teleconference on August 2, 2010.

primary oyster processor to FTSI if a signed agreement is established between the primary oyster processor and FTSI and both operations have HACCP plans to ensure that prelabeled oysters are irradiated before entering the market.

Because of the location of the facility, use of irradiation will only be feasible for a portion of the Gulf region. For the geographic information system (GIS) analysis presented below, we assumed that only facilities within a 4-hour drive might use irradiation as a PHP method. However, the majority of Gulf oyster harvests are processed at operations more than a day's drive. For example, the distance from New Orleans, Louisiana, to Mulberry, Florida, is nearly 700 miles, which equates to approximately 11 hours of driving time according to Google Maps (maps.google.com).

4.3 FEASIBILITY OF POST-HARVEST PROCESSING OF SUMMER-HARVESTED GULF OYSTERS

The feasibility analysis considers the following:

- calculation of the existing PHP capacity for summer-harvested Gulf oysters,
- evaluation of the possibility of using central PHP facilities on a toll basis, and
- a GIS analysis to determine optimal locations for central PHP facilities (aside from the irradiation facility in Mulberry, Florida).

PHP of all summer-harvested Gulf oysters will require sufficient treatment capacity to handle the volume of oysters harvested in a cost-efficient manner. To determine the feasibility of PHP, we calculated the existing capacity in the Gulf, evaluated the possibility of toll processing using existing or potential private facilities, and evaluated the possibility of toll processing using potential public facilities (or central PHP facilities). In considering the possibility of central PHP facilities, we conducted a GIS analysis to determine the general locations that would minimize travel time and costs for operations that currently have no or insufficient treatment capacity. As a result of the reasons noted previously regarding the infeasibility of using IQF in the summer because of quality and consumer acceptability problems, we excluded IQF treatment capacity from the analysis.

We assumed that the following types of operations from the ICSSL would be required to either install PHP equipment or identify another location that would offer toll-processing services:

- Shellstock shipper (SS): grows, harvests, buys, or repacks and sells shellstock. They are not authorized to shuck shellfish or to repack shucked shellfish. A shellstock shipper may also ship shucked shellfish.

- Repacker (RP): repacks shucked shellfish from a certified shucker-packer into other containers. A repacker also may repack and ship shellstock but may not shuck shellfish.
- Shucker-packer (SP): shucks and packs shellfish. A shucker-packer may act as a shellstock shipper or reshipper or may repack shellfish originating from other certified dealers.

In contrast, we assumed that reshippers, of which there are relatively few on the ICSSL, would not install PHP equipment or use toll-processing services because they are not engaged in processing. Instead, we assumed that reshippers would rely on shellstock-shippers and shucker-packers to process oysters as required. We then eliminated establishments that do not handle oysters or only shuck oysters using information obtained by the ISSC from the Gulf state agencies. To conduct the GIS analysis described below and the closure analysis described in Section 5.1, we augmented the ISCCL data with financial information from Dun & Bradstreet (D&B) and applied certain assumptions to estimate oyster processing volumes.[11] To ensure that the estimated oyster processing volumes provided an appropriate representation of industry volumes, we calibrated the estimated volumes to 2008 harvest volumes in the Gulf.

4.3.1 Existing PHP Capacity in the Gulf

Existing PHP capacity in the Gulf for summer-harvested oysters is currently insufficient to allow for PHP of all oysters intended for the half-shell market; thus, additional capacity will need to be installed to meet PHP requirements.

Table 4-4 provides a summary of key assumptions regarding oyster industry volumes and calculations of current PHP capacity in the Gulf. Based on information obtained from state agencies and industry participants, an estimated 40% of Florida-West Coast, 70% of Louisiana, and 75% of Texas oysters harvested from the Gulf in the summer months (April through October) are used for half-shell consumption.

Essentially no oysters harvested from Alabama and Mississippi during the summer are used for half-shell consumption. Overall, for half-shell and shucked oysters, an estimated 30% of Florida-East Coast, 75% of Louisiana, and 50% of Texas oysters harvested from the Gulf in the summer and intended

[11] An alternative approach would have been to conduct an industry survey to obtain facility-specific data on half-shell and shucked oyster volumes. However, conducting a survey would have required obtaining OMB approval, which is a lengthy process. Furthermore, because response rates for voluntary surveys are frequently low, the survey data would have had to have been augmented with D&B data to develop a complete data set.

Table 4-4. Oyster Industry Assumptions, Volume Estimation, and PHP Capacity Calculations
Current PHP capacity in the Gulf is insufficient to post-harvest process summer-harvested oysters.

	Alabama	Florida-West Coast	Louisiana	Mississippi	Texas	Total
Percentage of total harvest used for half-shell consumption in the summer[a]	0%	40%	70%	0%	75%	
Percentage of total harvest shipped interstate (applies to half-shell oysters)[a]	NA	30%	75%	NA	50%	
Harvest volumes: Summer 2008 (April–October)						
Meat-weight (pounds)[b]	30,929	1,297,429	6,779,514	1,009,136	914,152	10,031,160
Meat-weight per 100-pound sack[c]	4	4	4	4	4	
100-pound sacks	7,732	324,357	1,694,879	252,284	228,538	2,507,790
No. of oysters per sack[c]	250	250	250	250	250	
No. of oysters	1,933,063	81,089,313	423,719,625	63,071,000	57,134,500	626,947,500
Estimated half-shell volume in summer	—	32,435,725	296,603,738	—	42,850,875	371,890,338
Estimated interstate half-shell volume summer	—	9,730,718	222,452,803	—	21,425,438	253,608,958
Estimated current and in construction PHP capacity in summer (cool pasteurization and HHP)[d]						
Maximum production with 1 shift/day, 5 days/week						69,650,000
Maximum production with 2 shifts/day, 6 days/week						167,160,000
PHP capacity required for 15% PHP of half-shell summer harvest	—	4,865,359	44,490,561	—	6,427,631	55,783,551
Percentage PHP capacity assuming 1 shift/day, 5 days/week[e]						
Relative to total summer harvest						11%
Relative to half-shell summer harvest						19%
Relative to interstate half-shell summer harvest						27%
Percentage PHP capacity assuming 2 shifts/day, 6 days/week[e]						
Relative to total summer harvest						27%
Relative to half-shell summer harvest						45%
Relative to interstate half-shell summer harvest						66%

Note: Although irradiation is not yet used as a PHP option, it provides additional capacity that is not accounted for in these calculations.

[a] Percentages obtained through discussions with state agencies and industry experts, all of which were generally in agreement.

[b] Harvest data were obtained from the NMFS.

[c] Estimated meat-weight pounds per sack for summer-harvested oysters are based on estimates provided by several industry participants.

[d] PHP capacity will increase further when AmeriPure builds a new facility in Myrtle Grove, Louisiana.

[e] PHP capacity is calculated for the Gulf states combined because product may be shipped to other states for treatment.

for half-shell consumption are shipped interstate (and thus are specifically subject to PHP requirements). Estimates of interstate shipments are not included for Alabama and Mississippi because shucked product will not be subject to PHP requirements.

From industry-provided data, we calculated maximum processing volumes for existing and planned HHP and cool pasteurization equipment in the Gulf assuming (1) 5 days of operating one 8-hour shift per day each week in the summer and (2) 6 days of operating two 8-hour shifts per day each week in the summer. In actual operation, processing volumes would be less than these calculated estimates because of inevitable equipment breakdowns or occasional unavailability of raw oysters. We then compared the available capacity with estimated Gulf oyster volumes. Because a large percentage of oysters are shipped across state lines for processing, we estimated the percentage availability at the total Gulf oyster industry level.

Based on these calculations, existing PHP capacity (including equipment just beginning operation at Prestige Oysters) during the summer (April through October) is approximately 70 million oysters assuming a PHP operating schedule of one 8-hour shift per day for 5 days per week or 167 million assuming a PHP operating schedule of two 8-hour shifts per day for 6 days per week. PHP capacity relative to total Gulf summer harvest ranges from

- 11 to 27% of the volume requiring PHP, assuming 5 days of operating one 8-hour shift per day each week or
- 27 to 66% of the volume requiring PHP, assuming 6 days of operating two 8-hour shifts per day each week.

The lower range of estimates assumes that all harvested oysters will be treated, while the higher range of estimates assumes that only half-shell oysters intended for interstate shipment will be treated. Operations that currently operate PHP equipment use the processes for both half-shell and shucked oysters because the processes make oysters easier to shuck and increase meat yields.

It is important to note that these estimates do not incorporate (1) IQF capacity because IQF results in unacceptable product when applied to summer-harvested oysters; (2) the planned

new operation for cool pasteurization in Myrtle Grove, Louisiana, which will be operated instead of the Franklin, Louisiana, facility unless a buyer purchases the Franklin facility; or (3) the irradiation capacity in Florida, which has not yet been used commercially for oysters but could provide treatment services for a large volume of oysters for facilities within a reasonable driving distance from the irradiation facility.

PHP capacity in the Gulf is currently above 15% of the summer harvest as assumed in the states' *Vibrio vulnificus* control plans.

We also compared the PHP capacity estimates to an estimate of 15% of the Gulf summer harvest volume because the Gulf states' *Vibrio vulnificus* plans, directed at a 60% illness reduction, assume 15% of the harvest volume is currently post-harvest processed. Calculated at the total-Gulf level, PHP capacity exceeds 15% of the Gulf harvest volume of oysters intended for the half shell even with the lower capacity estimate. On a state-by-state basis, all individual states have sufficient capacity to post-harvest process 15% of their Gulf harvest volumes of oysters intended for the half-shell market assuming that (1) oysters harvested from Florida and intended for the half-shell market will be irradiated, (2) no oysters harvested from Alabama and Mississippi in the summer will be directed to the half-shell market, and (3) the Prestige Oyster facility in San Leon, Texas, is fully operational.

We also considered the possibility of shipping Gulf oysters to other regions for PHP. However, only one oyster processor operates HHP equipment outside of the Gulf, and no oyster processors operate cool pasteurization equipment outside of the Gulf. Transportation distance and cost from the Gulf to the one HHP processor in Washington State would prevent its use from being economically feasible.

4.3.2 Feasibility of Toll Processing Using Existing or Potential Capacity for Gulf-Harvested Oysters

Use of toll-processing services provided by other PHP processors in the Gulf is currently infeasible because of insufficient available PHP capacity and logistical concerns.

Many smaller oyster operations in the Gulf may be unable to install PHP equipment in their facilities for a number of reasons, including that they

- have insufficient product volume relative to the smallest available PHP equipment,
- lack sufficient floor space to install PHP equipment without costly plant expansion (and possibly land purchase),
- lack financial resources or access to credit to purchase processing equipment and expand plant floor space, and

- lack a labor force with required skills to operate PHP equipment.

As discussed previously, shifting to only shucked production in the summer is not economically feasible given the substantially lowered yields for shucked oysters in the summer. However, one option might be for these operations to obtain PHP services on a toll basis through an existing PHP operation with excess capacity.

To use toll-processing services, oysters will need to be shipped from a processor location to a central PHP facility rather than from a harvest location. Prior to PHP, harvested oysters must be cleaned, sorted, and banded. Oyster processors would most likely conduct these initial activities within their establishment to maintain quality and oversight of their products. Oyster processors might also transport oysters back to the original facility for final packaging and shipping orders to buyers. Thus, oyster processors will have to purchase containers for shipping to and from the toll-processing facility and obtain additional refrigerated transportation by purchasing trucks or using a trucking company. As a result, the costs associated with using a toll-processing facility will be substantially higher than the per-oyster PHP costs described in Section 4.2. Furthermore, it is likely that oyster processors would only use toll-processing services for half-shell oysters and, therefore, would not receive the yield increases or shucking labor savings associated with applying the process to oysters intended for shucking. In addition to incurring costs of using toll-processing services, the time required for transportation and conducting PHP activities will reduce the saleable time period for raw oysters.

For oyster processors located within a cost-effective transportation distance from the irradiation facility in Florida, toll processing could be established in a relatively short period of time assuming that consumer acceptability issues are not a concern. None of the other PHP operations in the Gulf (cool pasteurization and HHP) currently have sufficient capacity to offer more than a relatively minor volume of toll processing if PHP requirements are applied to all summer-harvested Gulf oysters. By operating more shifts or more days of the week, existing PHP operations would likely only be able to ensure that all of their own product was post-harvested processed, which would have to be above and beyond what they currently process. Furthermore, the one HHP operation in Texas only has

sufficient capacity to post-harvest process a small portion of its own production volume.

During the industry interviews we conducted, interviewees did not entirely rule out the possibility of toll processing by existing operations, but they expressed concern about the logistical challenges of providing treatment services. They noted these specific concerns:

- Oysters are not as standardized and mechanized as other products that are toll processed; thus, additional technical challenges will need to be resolved.
- Transportation to and from the toll-processing facility would require separate refrigerated trucks to deliver and retrieve oysters because of the time required to post-harvest process oysters, so transportation will be costly.
- Following treatment, oysters would have to be returned to the original processor so that orders could be prepared correctly, which will result in a lengthy time period for use of toll processing.

Some interviewees also expressed concern about insufficient trust in the industry for toll processing to function. Also, one company that experimented with toll processing found that its oysters did not receive sufficient priority by the toll processor. As discussed in the next section, some, but not all, of the concerns regarding toll processing using existing PHP processing capacity would be alleviated by using central PHP facilities operated by a local or state entity.

4.3.3 Feasibility of Using Central PHP Facilities for Gulf-Harvested Oysters

Depending on assumptions used in the analysis, five or six central PHP facilities would be required to ensure that all Gulf oyster operations currently without PHP equipment would have access to PHP services.

For the reasons noted above in Section 4.3.2, use of central PHP facilities may be the only viable option, other than closure in the summer, for smaller oyster operations that lack the volume and resources to install their own PHP equipment. Although PHP facilities could be established as private enterprises, the oyster industry should consider whether facilities established by local or state agencies may be more effective in ensuring access to PHP services by all oyster processors and, thus, preventing closure of operations. Obtaining financing for a central PHP facility may be particularly difficult for a private enterprise given the risks associated with handling a highly perishable product and the variability of oyster harvest volumes over time. Operation of a central PHP

facility would help alleviate industry concerns regarding trust in the organization and, given the perishability of raw oysters, help ensure that oysters would be post-harvest processed quickly without preference to certain processors.[12]

If the Gulf oyster industry made the decision to develop central PHP facilities, one of the first issues of concern would be where to locate the facilities. We conducted a GIS analysis to identify locations for potential consideration. In conducting the GIS analysis, we assumed that oysters would be shipped from a processor location to a central PHP facility to allow for preprocessing activities (cleaning, sorting, and banding) at the processor location. Oysters would then be either shipped back to the processor location for final packaging and order fulfillment or directly to a buyer. As discussed in Section 4.3.2, oyster processors would, therefore, incur costs for refrigerated shipping to and from the central PHP facility in addition to the costs of PHP services. Furthermore, the central facility may need to include an additional fee to compensate investors depending on how the operation is financed.

The data used in the analysis were based on pre-oil spill time periods so that the effects of PHP requirements would be distinguishable from the substantial effects of the oil spill on oyster harvests and oyster processors.

Prior to conducting the GIS analysis, we took several steps to estimate approximate oyster processing volumes for Gulf oyster processing establishments. As noted above, obtaining specific processing volumes would have required conducting an industry survey, which would have required time and resources beyond those available for the study. We began with shellstock shippers, repackers, and shucker-packers on the ISSCL as obtained from FDA's Web site in fall 2009 (prior to the effects of the oil spill) and eliminated establishments that appeared to be primarily distributors not involved in oyster processing, such as Sysco and U.S. Food Service.[13] The ICSSL does not indicate which types of shellfish are handled by each operation and whether shucker-packers handled shellstock in addition to shucking shellfish. Thus, on our behalf, ISSC contacted each of the Gulf state agencies to determine which shellstock shippers, repackers, and shucker-packers should be excluded from the

[12] Most cooperative type operations in the food industry have been established to provide marketing services to the processors that participate. However, some cooperatives have been established to provide food safety services or have incorporated food safety standards into their protocols. Examples include VeriPrime Beef Food Safety Cooperative and Pioneer Growers Cooperative.

[13] We excluded reshippers based on the assumption that they would most likely rely on other processor types to apply PHP.

analysis because they do not handle oysters or only shuck oysters. In determining which to eliminate, they used the list of establishments from the ICSSL for 2009 to be consistent with a pre-oil spill baseline. As a result of this process, the initial list of over 200 establishments was reduced to 138 that are believed to handle oyster shellstock.

We obtained financial data from D&B by matching the establishment name and address with records in the D&B data set. For establishments that were not identified in D&B, we manually searched for online information from Manta (www.manta.com), DNB Power Profiles (dnb.powerprofiles.com), and company Web sites. For establishments that were not matched using these data sources, we assumed the establishment was very small and applied the state average revenue estimates for establishments with one to five employees. In cases where only ranges were available, we applied the midpoint of the range prior to calculating the state average revenue estimates.

We then followed several steps to convert the revenue estimates into estimated numbers of oysters processed by each establishment. For shellstock shippers, we divided the revenue estimate by an estimated wholesale value for half-shell oysters of $0.15 based on information provided by several industry interviewees. For shucker-packers and repackers, we divided the revenue estimate by a weighted average estimate for wholesale shucked and half-shell oysters according to the state in which the establishment is located assuming an estimated price for half-shell oysters of $0.15 and for shucked oysters of $0.12.[14] To account for the fact that many shippers handle products other than oysters and, thus, their revenue estimates represent other types of products, we scaled back the volumes to account for other products. For processing operations with only "oysters" in the company name, we assumed 90% of the volume is oysters. For processing establishments with "oysters" and another term such as "seafood" or "fish," we assumed 38% of the volume is oysters. Finally, for processing operations without "oysters" in the company name, we assumed 5% of the volume was oysters, and, for restaurant-type operations, we

[14] The weighted average values were $0.141 for Alabama, Louisiana, and Mississippi assuming 70% half shell; $0.147 for Florida assuming 90% half shell; and $0.144 for Texas assuming 80% half shell.

assumed 15% of the volume was oysters. These percentages were determined by calibrating the estimated volumes for operations on the shippers list to 2008 harvest volumes as reported by NMFS.

We also adjusted the volumes produced by existing PHP processors by subtracting their PHP volumes from their total volumes to obtain an estimate of the remaining volume of oysters that would need to undergo a PHP process. For IQF operations, this meant scaling down their volumes by 10 to 100% based on information provided by the establishment regarding the proportion of product that undergoes the IQF process. For establishments operating cool pasteurization or HHP processes, we assumed that they would increase their PHP processing capacity and volumes to accommodate all product produced. Finally, we divided the estimated number of oysters by 12 to represent an average month in 2008. The final estimate was used for Scenario 1 of the analysis assuming that half-shell and shucked oysters whether shipped interstate or intrastate would be post-harvest processed. This provides an upper-bound estimate of the total number of oysters that would be post-harvest processed. Because of potential increased yields and reduced shucking labor associated with PHP of shucked oysters, many establishments might also post-harvest process shucked oysters. We also considered another scenario in which only interstate shipments of half-shell oysters would be post-harvest processed. Because no data are available on whether individual establishments receive or ship oysters interstate or what proportion of oyster shipments are shucked versus half shell, we reduced all establishment volumes by the same proportion. Specifically, for shellstock shippers, we multiplied their estimated volumes by 70% to represent interstate shipments only, and for shucker-packers, we multiplied their volumes by 42% (70% interstate shipments of 60% half-shell volume) to represent interstate half-shell oyster shipments only.

We then considered the following scenarios:

- All summer-harvested Gulf half-shell and shucked oysters whether shipped intrastate or interstate would be treated using cool pasteurization or HHP.
- Only half-shell oysters shipped interstate would be treated using cool pasteurization or HHP.

- Same as Scenario 2 but assuming all half-shell oysters produced in establishments within a 4-hour drive of the irradiation facility in Florida would be irradiated.

We assumed that a central PHP facility would have at most a monthly treatment capacity of 70 million oysters per month based on a 687 L HHP processor operating 4,800 hours per year or the equivalent of two cool pasteurization units also operating for 4,800 hours per year.[15] To determine the optimal locations for central PHP facilities, we used ESRI's Network Analyst software within ArcMap with the following optimization criteria:

- minimize the travel distance from the original establishment to the central PHP facility using major highways, and
- require that the central PHP facility be within a 4-hour drive from the original establishment to allow for drivers to return in the same day.

The results of the analysis identified the optimal PHP facility locations by zip code as listed in Table 4-5. Figures 4-1 through 4-3 show the central PHP facility locations in relation to oyster processor locations for each of the three scenarios.

Because many of the operations along the East Coast of Florida may not handle oysters harvested on the West Coast, the required capacity in Florida may be overstated in the analyses. Also, a few operations, particularly in inland areas and the southern coastal areas of Texas, are outside of a 4-hour driving distance of the identified locations; however, these operations may potentially not be handling oysters or not handling oysters harvested in the summer.

[15] Once the new AmeriPure facility is operational in Myrtle Grove, Louisiana, the existing AmeriPure facility in Franklin, Louisiana, with an annual treatment capacity of 36.4 million oysters will be available (assuming 2,080 operating hours per year). The capacity of the Franklin facility could be hypothetically increased to approximately 87 million oysters by operating 4,800 hours per year.

Table 4-5. Results of GIS Analysis to Determine Optimal Locations for Central PHP Facilities
Depending on the scenario, five or six central PHP facilities would allow for PHP of all Gulf-harvested oysters within a 4-hour drive of the processing facility.

Central PHP Facility Scenario	Approximate Locations (Required Monthly PHP Capacity)	Average (Maximum) Distance from Oyster Processors to Central PHP Facility
Scenario 1. All summer-harvested Gulf half-shell and shucked oysters whether shipped intrastate or interstate would be treated using cool pasteurization or HHP	San Antonio, TX 78279 (6.0 million)	149 miles (284 miles)
	Bayou La Batre, AL 36509 (4.8 million)	40 miles (95 miles)
	New Orleans, LA 70195 (4.7 million)	43 miles (190 miles)
	Houma, LA 70361 (4.6 million)	43 miles (220 miles)
	St. Augustine, FL 32086 (2.5 million)	86 miles (206 miles)
	Apalachicola, FL 32329 (1.4 million)	21 miles (75 miles)
Scenario 2. Only half-shell oysters shipped interstate would be treated using cool pasteurization or HHP	Houma, LA 70361 (3.0 million)	43 miles (220 miles)
	San Antonio, TX 78279 (2.6 million)	149 miles (284 miles)
	New Orleans, LA 70142 (2.5 million)	43 miles (190 miles)
	Bayou La Batre, AL 36509 (2.4 million)	40 miles (95 miles)
	St. Augustine, FL 32086 (1.4 million)	86 miles (206 miles)
	Apalachicola, FL 32329 (0.7 million)	21 miles (75 miles)
Scenario 3. Same as Scenario 2 but assuming all half-shell oysters produced in establishments within an 4-hour drive of the irradiation facility in Florida would be irradiated	Houma, LA 70361 (3.0 million)	43 miles (220 miles)
	San Antonio, TX 78279 (2.6 million)	149 miles (284 miles)
	New Orleans, LA 70142 (2.5 million)	43 miles (190 miles)
	Bayou La Batre, AL 36509 (2.4 million)	40 miles (95 miles)
	Apalachicola, FL 32329 (0.7 million)	21 miles (75 miles)

Figure 4-1. Results of GIS Analysis for Scenario 1: Locations for Central PHP Facilities Assuming All Summer-Harvested Gulf Oysters Undergo Cool Pasteurization or HHP

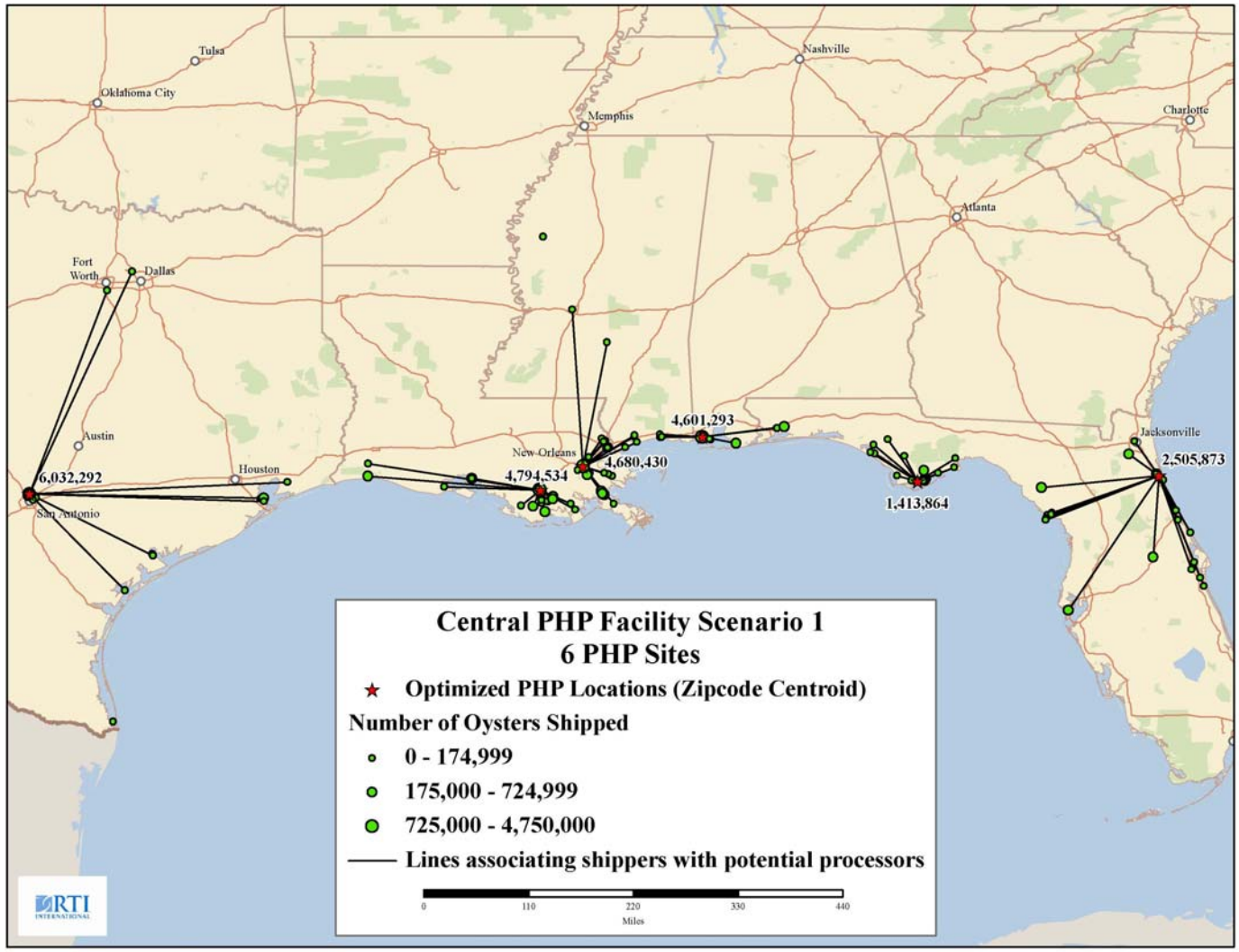


Figure 4-2. Results of GIS Analysis for Scenario 2: Locations for Central PHP Facilities Assuming Only Summer-Harvested Gulf Oysters Intended for the Half-Shell Market Undergo Cool Pasteurization or HHP

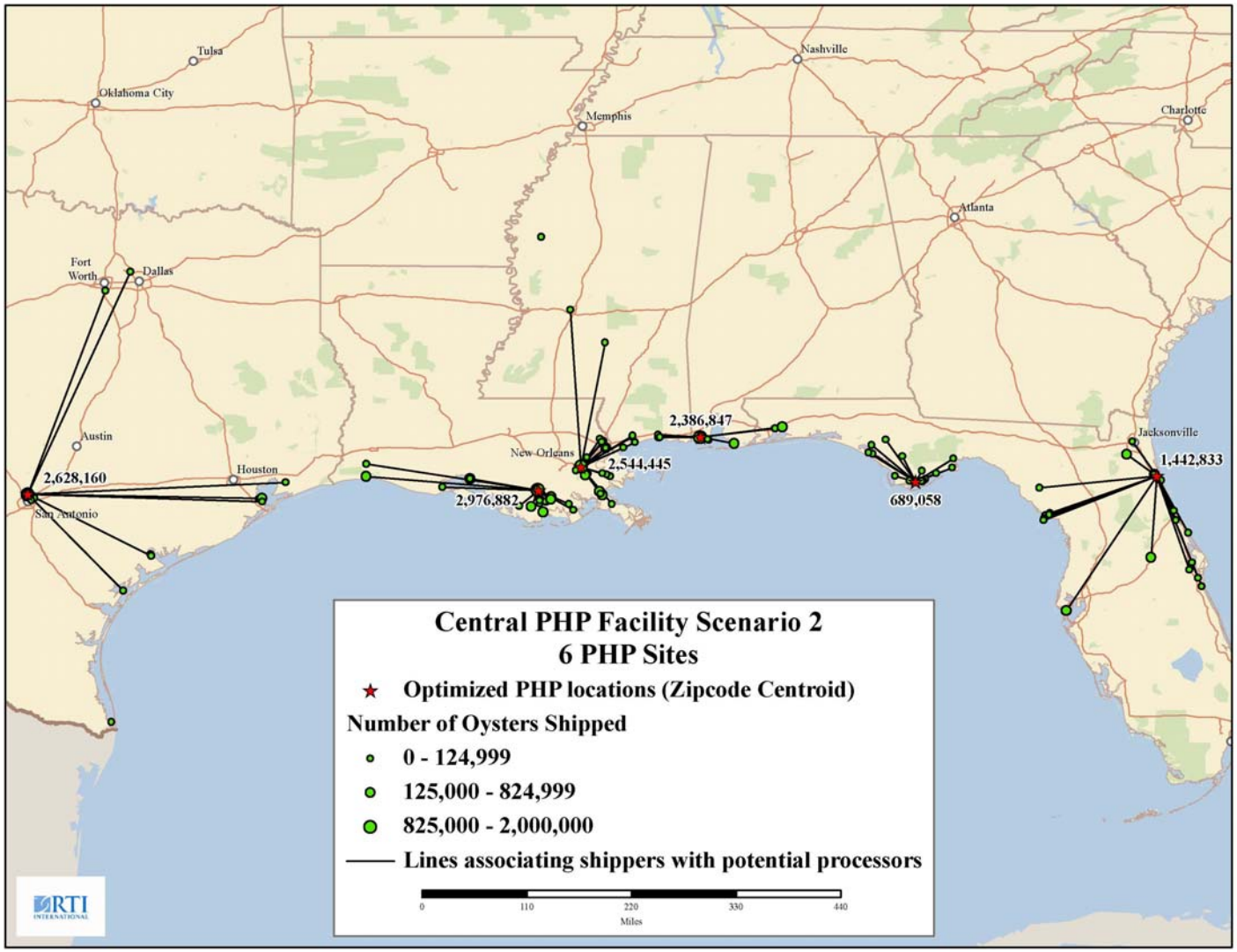
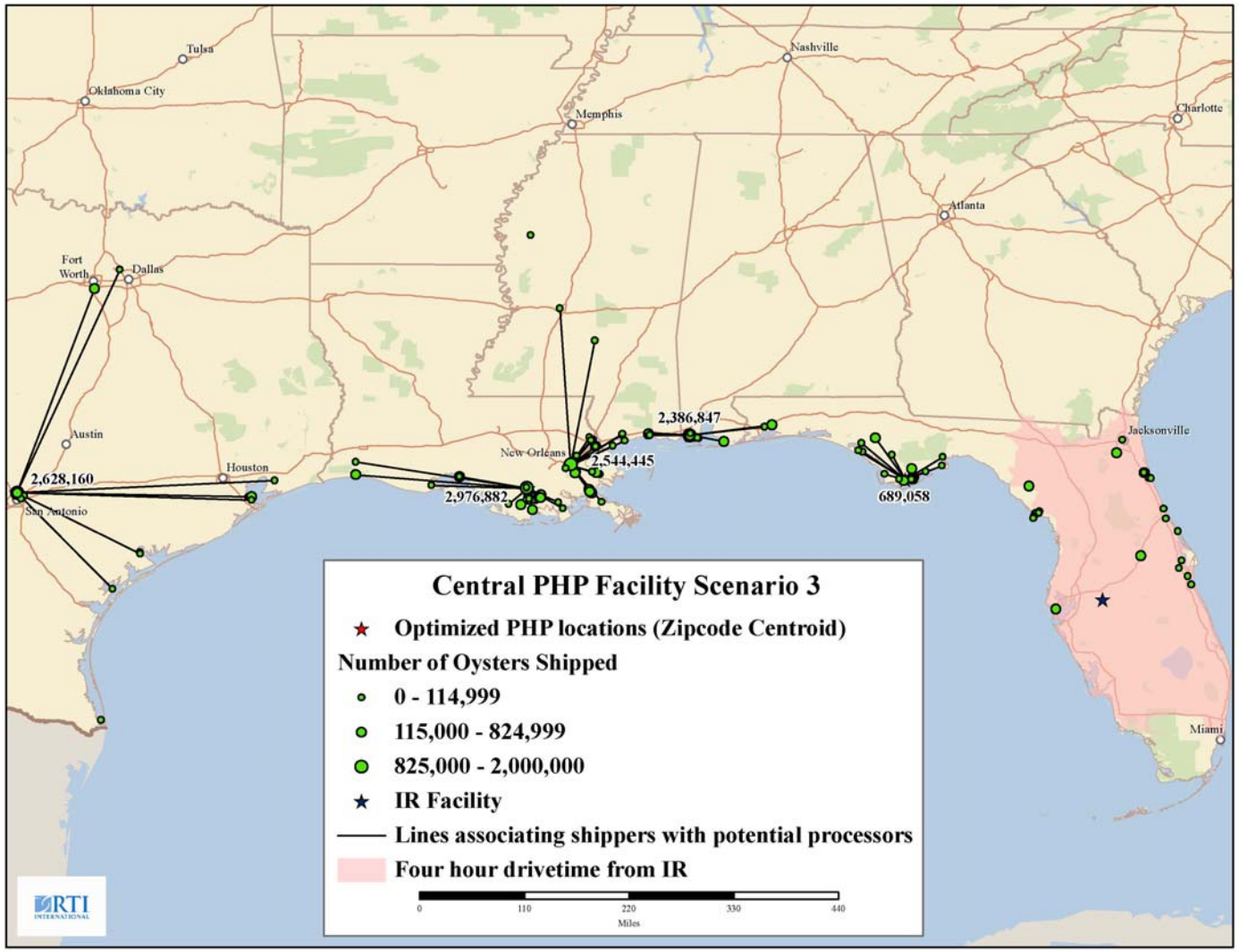


Figure 4-3. Results of GIS Analysis for Scenario 3: Locations for Central PHP Facilities Assuming Only Summer-Harvested Gulf Oysters Intended for the Half-Shell Market Undergo Cool Pasteurization, HHP, or Irradiation



Under all scenarios, optimal locations included zip codes 32329 (Apalachicola, Florida), 36509 (Bayou La Batre, Alabama), 70142 or 70195 (New Orleans, Louisiana), 70361 (Houma, Louisiana), and 78279 (San Antonio, Texas) but with varying capacity requirements. Under Scenarios 1 and 2, zip code 32086 (St. Augustine, Florida) was also identified as an optimal location. Under Scenario 3, the St. Augustine, Florida, location is not necessary because we assume that processors within a 4-hour drive of the irradiation facility would use irradiation to post-harvest process oysters.

Mean driving distances from processor locations to the optimal locations range from 21 miles for the Apalachicola, Florida, location to 149 miles for the San Antonio, Texas, location. In Alabama and Louisiana, the mean driving distances are approximately 40 miles. Maximum driving distances range from 75 miles for the Apalachicola, Florida, location to 284 miles for the San Antonio, Texas, location.

If central PHP facilities were developed in these or other locations, the time required to install and begin operating the processes would include

- determining the legal and operating structure of the operation;
- securing financing for the operation;
- identifying a specific property with the intent of modifying an existing facility or building a new facility;
- developing plans for expanding and altering an existing facility or building a new facility;
- obtaining necessary permits;
- constructing the facility and hooking up electrical, natural gas, and water supplies;
- purchasing and installing equipment;
- validating and verifying the process;
- hiring and training workers to operate and maintain the equipment;
- preparing a HACCP plan;
- conducting test operations; and
- conducting outreach and education to the industry to develop the clientele.

The time required for this sequence of activities is estimated by RTI to be a minimum of 3 years. Additional time is required beyond the estimate for a private enterprise because of the requirements for determining the type of organization for operating the facility and for identifying an appropriate facility or building on vacant property. Because small oyster operations will more likely need to rely on using a central PHP facility, they will require more time to comply with the requirements for PHP compared with larger operations. Furthermore, this estimate assumes that the equipment manufacturers could fulfill all orders as they are received and have sufficient staff available to support the delivery and installation of the equipment and training of staff. It is currently unknown whether the equipment manufacturers could satisfy these needs.

5 Business Closure and Market Assessment

Using the data discussed in previous sections on the costs of PHP methods, market prices and volumes for Gulf oysters, and oyster establishment data, we conducted analyses to determine whether oyster processors would close in response to PHP requirements and to estimate the market-level effects of the requirements on half-shell and shucked oysters in the Gulf relative to other oyster-producing regions. The results of the analysis are couched in terms of the specific assumptions required to conduct the analysis. Specifically, a number of issues are currently unknown, such as

- whether states will allow intrastate shipments of oysters that have not undergone PHP and which oyster processors would elect to ship only intrastate if that were the case;
- how consumers would respond if only oysters that have undergone PHP were available, both in terms of what portion of consumers would continue to consume oysters or substitute another product and what portion would be willing to pay more or less for oysters that had undergone PHP; and
- whether the industry or Gulf oyster agencies will be in a position to establish central PHP facilities to provide PHP services for establishments that are unable to install PHP equipment.

In the analyses presented in this section, we state our assumptions in conducting the analysis and provide a range of estimates reflecting uncertainty in the underlying data and assumptions.

5.1 BUSINESS CLOSURE ASSESSMENT OF PHP REQUIREMENTS

The business closure assessment assesses the extent to which oyster processors have sufficient product volumes to cost-effectively install PHP equipment within their establishments and whether oyster operations would remain profitable if they incur additional costs associated with PHP services (by operating installed equipment or using a central PHP facility). The methodology is similar to a cash flow method in which estimated revenues are compared with estimated costs, assuming no changes in market prices in response to PHP requirements.

Oyster establishments might close in response to PHP requirements for the following primary reasons:

- The size of the operation is small relative to the capacity of the available PHP equipment, which makes installing and operating the equipment extremely costly for the establishment. Thus, without the availability of central PHP facilities, the operation has no feasible method of PHP of oysters.
- The operation has sufficient volume relative to the capacity of the available PHP equipment, but the annual costs of treatment exceed the profits of the establishment; thus, the operation would lose money if it continued operating.
- The operation does not have sufficient volume to warrant installation of PHP equipment but has access to a central PHP facility, yet the annual costs of PHP services exceed the profits of the establishment.

Note that a closure might mean that an establishment discontinues processing oysters in the summer only or throughout the year or that it shuts down entirely if the primary line of business for the operation is oyster processing.

We conducted the analysis in stages, first considering processing volumes relative to the capacity of PHP equipment and second considering the costs of PHP relative to company profits. We based the analysis on the shippers list augmented with D&B data, as described in Section 4.3.3.

An estimated 6 to 11 oyster processing establishments, of an estimated total of 138, have sufficient product volumes to warrant installing at least the smallest available PHP equipment.

In the first stage, we compared estimated oyster product volumes relative to the capacity of PHP equipment available in the marketplace. For the cool pasteurization process, the small process is designed for an annual processing volume of approximately 4.5 million oysters, assuming 2,080 operating hours per year (see Table 4-1). For the HHP process, the smallest size equipment (100 L) is designed for an annual processing volume of approximately 6.6 million oysters assuming 2,000 operating hours per year (see Table 4-2).[1] Because these processes provide benefits in terms of reduced shucking labor or increased shucked oyster yields, operations that install these processes will likely apply PHP to both half-shell and shucked oysters. However, operations could decide to apply PHP only to half-shell oysters shipped interstate. Thus, we compared total oyster volumes and half-shell oyster interstate shipment volumes for each oyster processing establishment against the estimated capacity for the smallest process operating 2,000 hours per year.

Without the availability of central PHP facilities or other type of toll processing, the 122 to 127 establishments with insufficient product volumes to warrant installation of PHP equipment would be at risk for closure during the summer months (if they do not already close in the summer).

As indicated in Table 5-1, an estimated 6 to 11 operations, which represent up to 60% of total Gulf oyster volumes, have sufficient product volumes to warrant installation of PHP equipment depending on whether all oysters or only half-shell oysters shipped interstate are processed. (Note that some of these operations currently also operate IQF equipment but only process a relatively small portion of their total product volumes using IQF during cool-season months.) Of the remaining 122 to 127 establishments with insufficient product volumes to warrant installation of PHP equipment, their estimated product volumes would account for only 10 to 19% of the capacity of the smallest size equipment. Thus, these remaining operations have substantially smaller volumes than the capacity of existing PHP equipment. Without the availability of central PHP facilities or other type of toll processing, the 122 to 127 establishments with insufficient product volumes to warrant installation of PHP equipment would be at risk for closure during the summer months (if they do not already close in the summer) regardless of the costs of PHP services. These establishments are estimated to employ approximately 2,440 to 2,640 workers.

[1] The 35 L machine was not included in the analysis because the initial purchase cost of $700,000 (excluding installation costs) is extremely high and out of reach for small operations.

Table 5-1. Results of Closure Analysis: Number of Establishments and Number of Employees Affected

Results assume that market prices will not change as a result of PHP requirements. However, to the extent that prices increases, the number of closures would be less than estimated here.

	Estimated No. of Establishments	Estimated Total No. of Employees
Baseline (pre-oil spill)[a]	138	3,500
Establishments currently with sufficient summer PHP capacity[b]	4	680
Establishments with sufficient volume to install PHP for summer oysters[c]	6–11	470–670
Establishments with insufficient volume to install PHP for summer oysters	122–127	2,440–2,640
Establishments with negative annual profits if adopt PHP:[d]		
– Establishments with sufficient volume to install PHP	3–8	400–600
– Establishments relying on central PHP facility	20	110

[a] The baseline number of establishments represents the number of shellstock shippers, repackers, and shucker-packers operating prior to the 2010 oil spill that are believed to handle shellstock oysters.

[b] One establishment that applies IQF to nearly all its volume of oysters was included in the estimate of establishments with sufficient summer PHP capacity under the assumption that it would not change its operation in response to PHP requirements.

[c] The lower estimate is based on half-shell volumes, while the higher estimate is based on shucked and half-shell volumes.

[d] Annual costs exceeding 4.8% of sales were assumed to result in negative annual profits given profit ratios for the industry.

In the second stage of the analysis, we considered the costs of PHP relative to the revenues of each oyster processing establishment. For the 11 establishments that may have sufficient product volumes to warrant installation of PHP equipment (under at least one scenario), we determined the optimal size equipment and operating schedule by comparing their product volumes with the capacities of the equipment at 2,000 or 4,800 operating hours per year in Tables 4-1 through 4-3. We assumed that operations that installed PHP equipment would apply PHP to all half-shell and shucked oysters processed during the summer months because total costs are lower if PHP

is applied to both types of oysters.[2] We then estimated total costs for these establishments by annualizing the capital equipment and installation costs presented in Tables 4-1 through 4-3 for the assigned equipment size and adding it to the per-unit operating costs assuming that all oysters from April through October would undergo the assigned PHP process.[3]

For at least 8 of the 11 establishments with sufficient processing volumes to warrant installation of PHP equipment, we estimate that the costs of the processes will exceed the profits of the establishment if the prices of oysters do not change in response to PHP requirements.

For at least 8 of the 11 establishments with sufficient processing volumes to warrant installation of PHP equipment, we estimate that the costs of the processes will exceed the profits of the establishment if the prices of oysters do not change in response to PHP requirements. Based on data available from Robert Morris and Associates, profits before taxes for establishments classified in North American Industry Classification System (NAICS) code 311712 for "Fresh and Frozen Seafood Processing" ranged from 0.6 to 4.8% from 2004 through 2009. With the exception of the three establishments with estimated PHP costs below 4.8% of revenue, the remaining establishments would have estimated costs of 6 to 26% of revenue. Thus, oyster prices would need to increase substantially to allow all 11 establishments to operate profitably after installing PHP equipment.

For the 122 to 127 establishments with insufficient product volumes to warrant installation of PHP equipment, we calculated the costs of PHP services assuming a central PHP facility would offer PHP services at a cost of 4.9 cents (corresponding to the largest size cool pasteurization process on a 2,080 hours per year schedule) or 5.4 cents (corresponding to the largest size HHP process on a 2,000 hours per year schedule) per half-shell oyster. These

[2] We did not separately consider costs for only applying PHP to oysters intended for the interstate shipments in establishments that have sufficient capacity to install PHP equipment. The decision regarding the application of PHP to all or some oysters is complex and will be affected by whether the state allows intrastate shipments of oysters that have not undergone a PHP process, whether the operation would apply PHP to all or some shucked oysters in addition to half-shell oysters, and whether the establishment would want to handle some oysters that have undergone a PHP process and others that have not given the product tracking, labeling, and potential liability concerns.

[3] The per-unit operating costs used in the calculation are less than the per-unit cost estimates presented in Tables 4-1 through 4-3, which include both operating costs and annualized per-unit capital equipment and installation costs.

establishments represent approximately 14% of total Gulf oyster industry volumes. We assumed that only half-shell oysters intended for interstate shipment would undergo PHP because oyster operations would likely seek to minimize shipping costs and the effort involved in obtaining PHP services. Of these establishments, approximately 20, employing approximately 110 workers, would have PHP costs that exceed estimated average profits of 4.8% if the prices of oysters do not change in response to PHP requirements. For these 20 establishments, estimated costs are 5 to 12% of revenue.

Initial investment costs for PHP equipment to allow for PHP for all Gulf-harvested summer oysters intended for half-shell consumption are estimated to be $6 million to $32 million. Annual costs, including annualized capital equipment costs, are estimated to be approximately $8 million per year.

Based on the calculations described above, the total estimated costs of PHP Gulf-harvested oysters during the summer months would be $7.9 to $8.1 million per year. This estimate includes the incremental costs of applying PHP to all oysters for the operations that currently operate post-harvest processes, the costs of installing and operating PHP in operations with sufficient capacity to warrant installation of PHP equipment, and the costs of PHP services in central PHP facilities for establishments that are too small to warrant installation of PHP equipment. The total initial investment costs for capital equipment, including plant space for installing the equipment but not the costs of purchasing land or an existing building, would be approximately $32.3 million, assuming that central PHP facilities used the HHP process.[4] Initial investment costs would be substantially less—approximately $5.6 million—assuming that central PHP facilities use the cool pasteurization process.[5]

5.2 MARKET ASSESSMENT OF PRICE AND QUANTITY EFFECTS OF PHP REQUIREMENTS

The closure assessment discussed in Section 5.1 assumed no changes in market prices in response to PHP requirements. However, based on economic theory, market prices would change if oyster processors are able to pass along at least a

[4] Of the $32.3 million, an estimated $21.5 million would be incurred by private enterprises and $10.8 million would be incurred by public enterprises that establish central PHP facilities. The estimate for central PHP facilities assumes installation of four 320 L HHP machines and two 100 L HHP machines.

[5] Of the $5.6 million, an estimated $3.2 million would be incurred by private enterprises and $2.4million would be incurred by public enterprises that establish central PHP facilities. The estimate for central PHP facilities assumes installation of 6 large size cool pasteurization processes.

portion of the costs of the PHP requirements to their buyers. Operations currently selling half-shell oysters that have undergone the cool pasteurization or HHP process report receiving premiums of 50 to 70% relative to traditional half-shell oysters. Some of the price premium is likely because the oysters have been specifically selected and sorted to be a better quality product in addition to undergoing a PHP process. If all half-shell oysters were required to be post-harvest processed, these oysters would no longer be a differentiated product in the marketplace from a safety perspective; therefore, price premiums received from buyers are likely to be less than current price premiums. Thus, one of the purposes of the economic model is to determine the extent to which oyster prices would change if all Gulf oysters were required to be post-harvest processed.

Accurately modeling the economic effects of PHP requirements is challenging for a number of reasons. Oyster processors are maximizing profits based on a fixed short-run supply of the primary input, shellstock oysters. Depending on the location and season, shellstock oysters may or may not be available, and the quality of those supplies can vary considerably. Furthermore, oyster processors are maximizing profits over the course of the year rather than month to month. Oyster processors are willing to accept prices that are below their costs for shucked oysters in the summer because they are seeking to satisfy their customer needs over the course of the year to retain those customers for the months of the year when shucking yields are higher and, thus, shucking oysters is profitable.

Modeling the economic effects of PHP requirements is complicated by the following:

- fixed short-run supply of shellstock oysters,
- profit maximization over the course of the year with varying conditions,
- possible allowance for intrastate shipment of oysters that have not undergone PHP,
- benefits obtained from applying PHP to oysters intended for shucking, and
- mixed consumer response to half-shell oysters that have undergone PHP.

Modeling the effects of PHP requirements is also complicated by the fact that depending on how the Gulf states choose to respond, some oyster processors may have the option of selling product only within the state of harvest. With the allowance of intrastate shipment of oysters that have not undergone a PHP process, the raw half-shell market becomes a differentiated product market but with one product substantially restricted by geographic location compared with the other. Furthermore, establishments that install PHP equipment would likely use the process for both half-shell and shucked oysters to reap the benefits associated with the processes for shucked oysters, while establishments that would have to rely on toll processing would likely use the process only for half-shell oysters. Thus,

there will be differential industry responses because of the possibility of only intrastate shipments and the treatment of half-shell versus shucked oyster by different industry segments.

Finally, although some consumers may prefer post-harvest processed oysters or be indifferent between post-harvest processed and traditional oysters, others may elect to no longer consume oysters if only post-harvest processed oysters are available or only consume traditional oysters if Gulf states allow for intrastate shipments of half-shell oysters that have not been post-harvest processed. Of those consumers who prefer or are indifferent about post-harvest processed oysters, it is uncertain whether consumers are willing to pay more for these oysters if only post-harvest processed oysters are available.

Incorporating all of these features into an economic model was infeasible because of substantial data limitations for the oyster industry and available time and resources for completing the study. However, use of the equilibrium displacement model approach from Muth et al. (2000, 2002) provides a general indication of the market-level effects of PHP requirements. The model accounts for shifting of product from the half-shell to shucked market or vice versa in response to market price changes resulting from changes in costs of producing half-shell and shucked oysters and also shifting of production between the Gulf region and other oyster producing regions.[6]

We modified the model presented in Muth et al. (2000, 2002) by updating the baseline data to an average summer (April through October) month in 2008 and allowing the user to enter individual supply (cost) and demand (willingness to pay) shift estimates for half-shell and shucked oysters based on the selected PHP scenario.[7] The updated baseline data are presented in Table 5-2. To develop the oyster quantity estimates for the baseline, we first calculated the average monthly harvest volumes in meat-weight pounds from NMFS's

[6] See Muth et al. (2002) and Muth et al. (2000) for a graphical representation of the market-level price and quantity effects of increased costs for producing half-shell oysters and reduced costs for producing shucked oysters.

[7] We also adjusted the cross-price elasticities in the model to reflect increased product flows between regions over time. Specifically, the cross-price elasticity for shucked oysters between regions was changed from 0.4 to 0.6, and the cross-price elasticity for half-shell oysters was changed from 0.2 to 0.4.

Table 5-2. Baseline Wholesale Oyster Industry Data: Average Summer Month for April–October, 2008

	U.S. Total	Atlantic (including East Coast Florida)	Gulf (with West Coast Florida)	Northeast	Pacific
Halfshell volume (output)		*25%*	*60%*	*90%*	*20%*
Meat-weight (pounds)	1,096,356	14,029	859,814	80,831	141,682
Shellstock weight (pounds)	27,400,000	400,000	21,500,000	2,000,000	3,500,000
No. of oysters	64,980,201	876,813	53,738,375	5,051,938	5,313,075
Shucked volume (output)		*75%*	*40%*	*10%*	*80%*
Meat-weight (pounds)	1,191,007	42,088	573,209	8,981	566,729
Shellstock weight (pounds)	29,800,000	1,100,000	14,300,000	200,000	14,200,000
No. of oysters	60,269,714	2,630,500	35,825,563	561,313	21,252,338
Shellstock volume (input)					
Meat-weight (pounds)	2,287,363	56,117	1,433,023	89,812	708,411
Shellstock weight (pounds)	57,100,000	1,400,000	35,800,000	2,200,000	17,700,000
No. of oysters	125,249,914	3,507,313	89,563,938	5,613,250	26,565,413
Halfshell price (output)					
Per meat-weight pound	$10.53	$12.44	$9.38	$28.50	$7.10
Per oyster	$0.18	$0.20	$0.15	$0.46	$0.19
Shucked price (output)					
Per meat-weight pound	$6.43	$8.71	$7.50	$19.95	$4.97
Shellstock price (input)					
Per meat-weight pound	$3.42	$6.98	$2.89	$11.21	$3.23
Per oyster	$0.07	$0.10	$0.05	$0.23	$0.09
Halfshell revenue	$11,544,629	$174,521	$8,065,055	$2,303,684	$1,005,942
Shucked revenue	$7,658,175	$366,586	$4,299,068	$179,171	$2,816,643
Shellstock cost	$8,303,128	$349,048	$4,170,097	$1,279,821	$2,514,859
No. of Plants					
Shucker-packers	288	76	102	68	42
Shellstock shippers	1,122	275	116	436	295

Assumptions:

- For summer months, we assumed 4 pounds of meat per 100-pound sack of 250 oysters except in the Pacific, where we assumed 4 pounds of meat per 150 oysters.
- Mark-ups were assumed to be 200% for half-shell oysters and 140% for shucked oysters relative to the shellstock price.

Sources:

Average shellstock volumes and prices were calculated from NMFS harvest data.
Number of plants was calculated from the ISSC-L excluding operations that are distribution companies (numbers include operations that may not handle oysters).

Monthly Commercial Landings Statistics for all oysters in each U.S. oyster producing region.[8] We then apportioned the meat-weight pounds to half-shell and shucked oysters using the percentages estimated from information provided by several industry experts (see Section 4.3). Assuming a 100-pound sack of 250 oysters (150 oysters in the Pacific) yields approximately 4 meat-weight pounds in the summer, we converted the meat-weight pounds to number of oysters and shell-weight pounds. To develop the oyster price data for the baseline, we calculated the average summer harvest price on a meat-weight basis from the NMFS data and then applied mark-up estimates of 200% for half-shell oysters and 140% for shucked oysters to obtain the wholesale price estimates. These mark-up estimates were calculated using estimates of the pre-oil spill wholesale price of half-shell and shucked oysters in the Gulf based on information provided by Gulf oyster processors. We calculated per-oyster wholesale prices from meat-weight wholesale prices by applying the same assumptions as for the quantity calculations. Wholesale revenues from half-shell and shucked oysters and shellstock costs were calculated by multiplying the meat-weight pounds by the price per meat-weight pound. Finally, we calculated the number of shellstock shippers and shucker-packers (excluding operations that appear to be distributors such as Sysco and U.S. Foodservice) in each region using the shippers list.

We then considered a minimum and maximum cost scenario from Section 4.2 as follows:

- Minimum cost scenario—PHP costs of 4.2 cents per half-shell oyster and −3.1 cents per shucked oyster
- Maximum cost scenario—PHP costs of 7.0 cents per half-shell oyster and -0.3 cents per shucked oyster

We assumed that consumers would be indifferent between post-harvest processed and traditional oysters; thus, demand would not increase or decrease in response to PHP requirements. Based on these model inputs, the predicted aggregate changes in key market variables are as follows:

- 5.6 to 11.5% increase in the price of raw half-shell Gulf oysters in the summer

[8] NMFS Monthly Commercial Landings Statistics are available at http://www.st.nmfs.noaa.gov/st1/commercial/landings/monthly_landings.html.

- 3.8% decrease (same for both scenarios) in the volume of raw half-shell Gulf oysters sold in the summer
- 3.7% decrease to 1.8% increase in the price of shucked Gulf oysters in the summer
- 3.0 to 5.0% increase in the volume of shucked Gulf oysters sold in the summer
- 0.5 to 1.8% decrease in the price of Gulf shellstock oysters in the summer
- 0.3 to 1.1% decrease in the volume of Gulf shellstock oysters purchased in the summer
- 1.7 to 3.8% increase in half-shell oysters and 0.8% decrease to 1.6% increase in shucked oysters produced in other regions of the country to compensate for changes in the Gulf region

The predicted increases in prices indicate that oyster processors can pass along some of the costs of PHP to buyers. However, it is unclear whether these increases are sufficient to allow all oyster processors to continue to operate profitably following implementation of PHP requirements. For some establishments, the predicted percentage increases in prices are less than percentages of PHP costs relative to revenue calculated in Section 5.1. Furthermore, if the Gulf states allow intrastate shipments of traditional oysters, the portion of PHP costs that oyster processors will be able to pass along to buyers is less than that predicted by the model because many buyers will not be willing to pay more for post-harvest processed oysters if a less costly traditional product is available in sufficient quantities to satisfy consumer demand.

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Appendix A: Interview Guides and Restaurant Questionnaire

This appendix contains the interview guides and restaurant questionnaire that were used to obtain information used to guide the study as follows:

- Exploratory List of Discussion Topics for the RTI Study, "Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented"
- List of Discussion Topics on Gulf Oyster Harvesting for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented (used for individual discussions)
- List of Discussion Topics on Gulf Oyster Harvesting for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented (used for a group discussion in Texas)
- List of Discussion Topics on Post-Harvest Processing for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented
- List of Questions for Gulf IQF Operations
- List of Discussion Topics for Restaurants that Serve Raw Oysters for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented
- Telephone Survey for Restaurants that Serve Raw, Untreated Gulf Oysters

In all cases, no more than nine respondents were interviewed with each of the unique set of questions.

``Exploratory List of Discussion Topics for the RTI Study, "Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented"

- Typical timeline from harvest to consumption for half-shell oysters harvested in the Gulf
    - Intrastate sales
    - Interstate sales
- Advantages, disadvantages, and likelihood of each potential industry response to PHP requirements (shippers, shucker/packers, and reshippers)
    - Only sell oysters intrastate (if states allow)
    - Install own treatment equipment
    - Contract with operation that has PHP equipment
    - Use central treatment facility (if developed)
    - Shift to shucked production only in the summer
    - Shift to seasonal operations only (that is, sell only in the winter)
- Types of factors affecting decisions regarding PHP treatment options
    - Volume of operation
    - Availability of floor space to install equipment
    - Availability of financing to purchase equipment
    - Location
    - Types of buyers the operation sells to
- Duration of phase in period needed for full compliance
- From the harvesters' perspective, effects of the PHP requirements on their operations and marketing practices
- General industry beliefs about total costs to install PHP equipment (note: we'll be collecting specific cost data from PHP processors later)
- General industry beliefs about cost per oyster for PHP (note: we'll be collecting specific cost data from PHP processors later)
- Expectations about consumer response/acceptance of treated oysters
    - Sensory characteristics
    - Potential benefits of safer oysters
- Expectations about effects of PHP on shelf-life

- Expectations regarding responses of restaurants—in the Gulf, East Coast, West Coast
    - Use treated oysters and sell at same price
    - Use treated oysters and sell at higher price (reflecting higher costs)
    - Use only intrastate oysters in the Gulf
    - Use oysters from outside the Gulf in the summer
    - Stop serving oysters
- Ballpark estimates of industry proportions for each Gulf state in the SUMMER
    - % of harvest that is shucked versus served on the half shell
    - % of half-shell oysters that are shipped intrastate versus interstate
    - % of half-shell oysters that are currently PHP treated versus untreated
    - % of shippers on the ISSCL that handle some volume of oysters (versus other shellfish or fish)
- Potential unintended consequences of PHP requirements on consumers and industry
- Recommended data sources and other industry contacts
    - Harvesters
    - Processors

List of Discussion Topics on Gulf Oyster Harvesting for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented

Note: Analysis will be conducted using 2008-2009 as the baseline with the stated assumption that oyster harvests will return to this level at some point in the future.

- Under normal conditions, general harvest locations in the summer and distance from oyster processing operations
- Under normal conditions, general types and number of customers
- Under normal conditions, typical monthly harvest volumes in the summer months (May-Oct)
- Estimated percentage of summer-harvested oysters that are typically used for raw half-shell consumption
- Estimated percentage of summer-harvested half-shell oysters that are typically shipped out of state
- Prior to the oil spill, anticipated changes in oyster harvesting and shipping in the summer if post-harvest processing was required
    - Potential shift from half shell to shucked product
    - Potential shift to other types of seafood products
    - Potential shift to selling to other oyster processing operations
    - Other changes
- Typical production values for use in calculations
    - Number of days of harvest per week
    - Weight of a sack of oysters in the summer
    - Weight of a sack of oysters in the winter
    - Number of oysters in a sack in the summer
    - Number of oysters in a sack in the winter
    - Pounds of meat per sack in the summer
    - Pounds of meat per sack in the winter
- Suggestions for other harvesters to interview

List of Discussion Topics on Gulf Oyster Harvesting for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented

Note: Analysis will be conducted using 2008-2009 as the baseline with the stated assumption that oyster harvests will return to this level at some point in the future.

- Under normal conditions, general harvest locations in the summer and distance from oyster processing operations
- Under normal conditions, general types and number of customers
- Under normal conditions, typical monthly harvest volumes in the summer months (April-Oct)
- Estimated percentage of summer-harvested oysters that are typically used for raw half-shell consumption
- Estimated percentage of summer-harvested half-shell oysters that are typically shipped out of state
- Anticipated changes in oyster harvesting and shipping in the summer if post-harvest processing was required
    - Potential shift from half shell to shucked product
    - Potential shift to other types of seafood products
    - Potential shift to selling to other oyster processing operations
    - Potential shift to oysters from other regions of the country
    - Stop selling oysters during affected months
    - Other changes
- Other anticipated changed in oyster processing in the summer if post-harvest processing is required
    - Potential installation of treatment equipment
        - Advantages and disadvantages
        - Estimated costs
        - Required time for installation (phase-in period)
    - Potential use of central PHP treatment facilities
        - Advantages and disadvantages
        - Potential locations

- Typical production values for use in calculations
    - Number of days of harvest per week
    - Weight of a sack of oysters in the summer
    - Weight of a sack of oysters in the winter
    - Number of oysters in a sack in the summer
    - Number of oysters in a sack in the winter
    - Pounds of meat per sack in the summer
    - Pounds of meat per sack in the winter

List of Discussion Topics on Post-Harvest Processing for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented

Note: Analysis will be conducted using 2008-2009 as the baseline with the stated assumption that oyster harvests will return to this level at some point in the future.

- General harvest locations and distance from the plant
- General types of customers (e.g., restaurants, retailers) and geographic areas
- Treatment volume for your operation in the summer (May-October) assuming a normal harvest year
- Potential treatment of oysters in your operation on a toll basis for other processors
    - Existing excess capacity (assuming a normal harvest year)
    - Amount of potential expansion of capacity
    - Expected toll charged on a per-oyster basis
    - Feasibility issues involved with providing treatment services
- Typical production values for use in calculations
    - Number of hours per shift
    - Number of shifts per day
    - Number of days of operation per week
    - Weight of a sack of oysters in the summer
    - Weight of a sack of oysters in the winter
    - Number of oysters in a sack in the summer
    - Number of oysters in a sack in the winter
    - Pounds of meat per sack in the summer
    - Pounds of meat per sack in the winter
- If a processor chose to install treatment equipment—treatment volumes in the summer (number of sacks or oysters) for a typical treatment process
    - Small process
    - Large process
- Plant expansion requirements for treatment process (square footage and costs)
    - Small process
    - Large process

- Capital equipment requirements (type of equipment, cost of equipment including delivery, and length of life)
    - Small process
    - Large process
- Capital equipment installation costs
    - Small process
    - Large process
- Operating costs—water (monthly)
    - Small process
    - Large process
- Operating costs—electricity and natural gas (monthly)
    - Small process
    - Large process
- Operating costs—additional labor (number of workers and hourly wage with benefits)
    - Small process
    - Large process
- Operating costs—materials (for example, oyster bands)
    - Small process
    - Large process
- Operating costs—maintenance and replacement parts (monthly or annual)
    - Small process
    - Large process
- Royalty or license fees for using the technology
- Changes in product yields for shucked product
- Percentage increase in price for treated product relative to untreated product
    - Half-shell oysters
    - Shucked oysters
- Feasibility of other types of treatment processes such as irradiation or salt water relaying
- Recommended contacts to discuss consumer response to treated oysters

List of Questions for Gulf IQF Operations

- Prior to the oil spill situation, what proportion of your annual oyster production (half shell and shucked) was IQF oysters?
- In a typical year, in what months do you freeze oysters using the IQF process?
- If you do not typically freeze oysters in the summer using the IQF process, what are the reasons why you don't?
- If you do typically freeze oysters in the summer using the IQF process, are there quality differences compared to winter oysters? (If yes, what kind of differences?)

List of Discussion Topics for Restaurants that Serve Raw Oysters for the FDA-Sponsored RTI Study: Analysis of How Post-Harvest Processing Technologies for Controlling *Vibrio vulnificus* Can be Implemented

Note: Analysis will be conducted using 2008-2009 as the baseline with the stated assumption that oyster harvests will return to this level at some point in the future.

- Under normal conditions, geographic locations and sources of oysters served raw on the half shell
    - Differences in geographic locations and sources of oysters based on time of year
- Under normal conditions, types of oysters most served frequently raw on the half shell in the summer
    - Traditional oysters (not post-harvest processed)
    - High pressure processed
    - Cool pasteurization processed
    - Frozen on the half shell (individual quick freezing or cryogenic freezing)
- If post-harvest processing was required for Gulf oysters harvested in the summer months (May-Oct), expected effect on oysters served in your restaurant
    - Serve only oysters harvested within the state (if the state would allow intrastate sales of unprocessed oysters)
    - Serve high pressure processed oysters
    - Serve cool pasteurized oysters
    - Serve frozen oysters
    - Serve only cooked oysters
    - Stop serving oysters
- If post-harvest processed oysters are or will be served in your restaurant, anticipated increase in menu price for half-shell oysters if post-harvest processed
- Anticipated response of customers if only post-harvest processed oysters were served
    - Effects of possible sensory changes
    - Effects of increased safety
    - Effects of possible price changes

Telephone Survey for Restaurants that Serve Raw, Untreated Gulf Oysters

Under contract with FDA, RTI is conducting a study on the costs and feasibility of post-harvest processing of Gulf-harvested oysters intended for raw half-shell consumption in the summer. We are collecting information from the oyster industry and restaurants that serve raw oysters to help guide the study.

RTI is an independent, university-affiliated research organization located in North Carolina. We conducted a previous study on post-harvest processing about 10 years ago.

Restaurant: _____

City: _____ State: _____

Have you served raw oysters from the Gulf during the past year (**prior to the oil spill**)?

Yes _____

No _____ (thank them and end call)

1. Which of the following best describes this restaurant? *(Circle one.)*
   1. Independently owned
   2. Part of a chain
   3. Other *(Specify):* _____

2. Which of the following best describes your position? *(Circle all that apply.)*
   1. Owner
   2. Manager
   3. Chef
   4. Seafood buyer
   5. Corporate office
   6. Other *(Specify):* _____

3. Are most of your restaurant sales from seafood or non-seafood items? *(Circle one.)*
   1. Seafood
   2. Non-seafood

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4. In which months do you serve raw Gulf oysters (**prior to the oil spill**)? *(Circle all **months** that apply.)*
   1. January
   2. February
   3. March
   4. April
   5. May
   6. June
   7. July
   8. August
   9. September
   10. October
   11. November
   12. December

5. Which of the following best describes trends in your ***raw*** Gulf oyster sales over the past 5 years (**other than trends resulting from the oil spill**)? *(Circle one.)*
   1. Significant increase in sales
   2. Slight increase in sales
   3. No change
   4. Slight decrease in sales
   5. Significant decrease in sales

6. About how many raw Gulf oysters do you purchase for half-shell consumption in a typical week during the summer (**prior to the oil spill**)?

   _____bushels/week or _____sacks/week or _____boxes/week

   (6a.) If boxes: number of oysters per box_____.

7. Under normal conditions, what types of Gulf oysters do you serve raw on the half shell in the summer?
   1. Traditional oysters (not post-harvest processed)
   2. Cool pasteurized (AmeriPure)
   3. Hydrostatic pressure processed
   4. Frozen on the half shell (IQF or cryogenic freezing)

8. If you answered only 1 (traditional oysters) in Question 7: Have you served any type of treated Gulf oysters in the past 5 years?
   1. No
   2. Cool pasteurized (AmeriPure)
   3. Hydrostatic pressure
   4. Frozen on the half shell (IQF or cryogenic freezing)

Contact: Michaela Cimini Coglaiti, coglaiti@rti.org, 919/990-8498 9/14/2010

9. If you answered 2, 3, or 4 in Question 8: If you are not currently serving treated Gulf oysters, but have in the past, why did you stop serving treated Gulf oysters?
   1. Consumer acceptance issues (quality, sensory)
   2. Shelf life problems
   3. Increased costs
   4. Other (*Specify*):_____

10. What is the harvest location for all raw oysters you generally purchase*? (Check all that apply.)*

Oyster Harvest Region	Raw in the Shell
Gulf Coast (AL, FL, LA, MS, TX)	
Northern Atlantic/Eastern Seaboard (CT, DE, MA, MD, ME, NH, NJ, NY, RI)	
Southern Atlantic/Eastern Seaboard (FL, GA, SC, NC, VA)	
California coast	
U.S. Pacific Northwest (AK, OR, WA)	
Canada	
Other area	
Not sure where they are harvested	

11. FDA is considering requiring post-harvest processing of Gulf oysters harvested in the summer and intended for half-shell consumption. If post-harvest processing were required for Gulf oysters harvested in the summer months, how would your restaurant respond?
   1. Serve only Gulf oysters harvested within the state (if the state would allow intrastate sales of traditional oysters)
   2. Serve hydrostatic pressure processed Gulf oysters
   3. Serve cool pasteurized (AmeriPure) Gulf oysters
   4. Serve frozen Gulf oysters
   5. Serve oysters from other regions of the country
   6. Serve only cooked oysters
   7. Stop serving oysters

12. If you serve (or would serve) treated Gulf oysters, how much more do you (or would you) charge for them relative to traditional Gulf oysters?

   $_____/dz

13. If you serve (or would serve) treated Gulf oysters, how do (or would) your customers react to each of the following:

    a. sensory changes associated with treated Gulf oysters?

    b. increased safety associated with treated Gulf oysters?

    c. possible price changes associated with treated Gulf oysters?

14. In general, have you found (or would you expect) consumers to respond favorably or unfavorably to treated oysters?

    a. favorably

    b. unfavorably

15. Do you have any concerns about serving treated Gulf oysters?

16. Would you like to receive a $75 honorarium for completing this survey? If yes, we will need your address and preferred phone number, and we will mail you a check within 2 weeks.

☐ No, I cannot accept the honorarium.
☐ Yes, I would like to receive the honorarium.

Name: _____

Address: _____

_____

_____

Telephone: Work: (__ __ __) __ __ __ - __ __ __ __ Home: (__ __ __) __ __ __ - __ __ __ __

Thank you for completing this survey.

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