The Demand for Eastern Oysters, *Crassostrea virginica*, from the Gulf of Mexico in the Presence of *Vibrio vulnificus*

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Introduction

The bacteria *Vibrio vulnificus* is a naturally occurring organism in estuarine waters and is found in an unknown proportion of eastern oysters, *Crassostrea virginica*, harvested from the Gulf of Mexico (hereafter, the Gulf). The presence of *Vibrio vulnificus* is highly correlated with water temperature, and virtually all Gulf-harvested oysters contain some concentration of it in the warmer summer months (McQuaid, 1997). As noted by Corcoran (1998) in the Nutrition Action Healthletter: "[e]very year, more than 50 people become ill and at least 10 die after eating uncooked Gulf Coast oysters that are contaminated with *Vibrio vulnificus* bacteria." Most of these illnesses and deaths occur between May and October.

California, in response to this health concern, initiated a program on 1 March 1991 which required anyone selling Gulf oysters to notify potential consumers that the "consumption of raw oysters can cause illness and death among people with liver disease, chronic illnesses, or weakened immune systems" (Liddle, 1991). California's mandatory warning received extensive coverage in newspapers (and the trade literature) both there and across the country and particularly in the Gulf region.[1]

In a further step to promote public safety, the U.S. Food and Drug Administration (FDA) in 1994 proposed banning consumption of raw oysters from the Gulf from April through October when *Vibrio vulnificus* was most prevalent. After "heavy pressure from the Gulf oyster industry and members of Congress from Louisiana and other Gulf states," the FDA backed away from its initial proposal and instead opted for a "public awareness campaign" to notify and educate those people at risk (McQuaid, 1997).

The primary goal of this paper is to examine the extent to which the demand for Gulf oysters has been reduced as a result of the mandatory warning labels and associated media attention and to examine the impact on consumer welfare associated with further regulation of the harvesting sector. A secondary goal of the paper is to analyze the impacts of other factors, such as the quantity harvested and income, on the demand for Gulf oysters. To accomplish these goals, an overview of the oyster industry is presented here, followed by a review of relevant literature. Then, the model used for the analysis is specified, and the data and estimation issues are briefly examined. The empirical results are then presented, and the paper concludes with a discussion of the implications of the findings.

Industry Overview

The U.S. oyster industry operates on both the U.S. east and west coasts. The primary oyster species harvested on the east coast (i.e. Atlantic and Gulf), the eastern oyster, produced average annual landings of about 31 million pounds during 1981–97 with an associated $77 million dockside value (NMFS[2]). Annual landings of Pacific oysters, *Crassostrea gigas*, the primary west coast species, averaged about 9 million pounds valued at $18 million (dockside) during 1981–97.

Gulf oyster production averaged 20 million pounds annually during 1981–97, or about 60% of the total eastern oyster production. Louisiana, the primary producer there, accounted for almost 60% of the Gulf output, while Texas accounted for an additional 20%.

Chesapeake Bay, once the nation's largest oyster source, has seen production fall sharply since the early 1980's

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ABSTRACT—California, in response to health concerns, initiated a program on 1 March 1991 which required anyone selling eastern oysters, Crassostrea virginica*, from the Gulf of Mexico area to notify potential consumers that there was a risk in consuming them raw. This mandatory warning, followed shortly thereafter by a similar warning in other states, including Louisiana and Florida, received extensive press coverage throughout the country and particularly in the Gulf area. This paper examines the extent to which the demand for Gulf-area oysters has been reduced as a result of mandatory warning labels and negative publicity. In general, the results suggest that since 1991 the "summer" dockside price has been reduced by about 50% as a result of warning labels and associated negative publicity, while the "winter" dockside price has been reduced by about 30%.*

[1] Subsequently, other states—most notably Louisiana and Florida—have enacted mandatory warning label programs similar to that of California.

[2] NMFS Commercial Fisheries Landings data compiled by the Fisheries Statistics and Economics Division, Office of Science and Technology available at http://www.st.nmfs.gov/commercial.

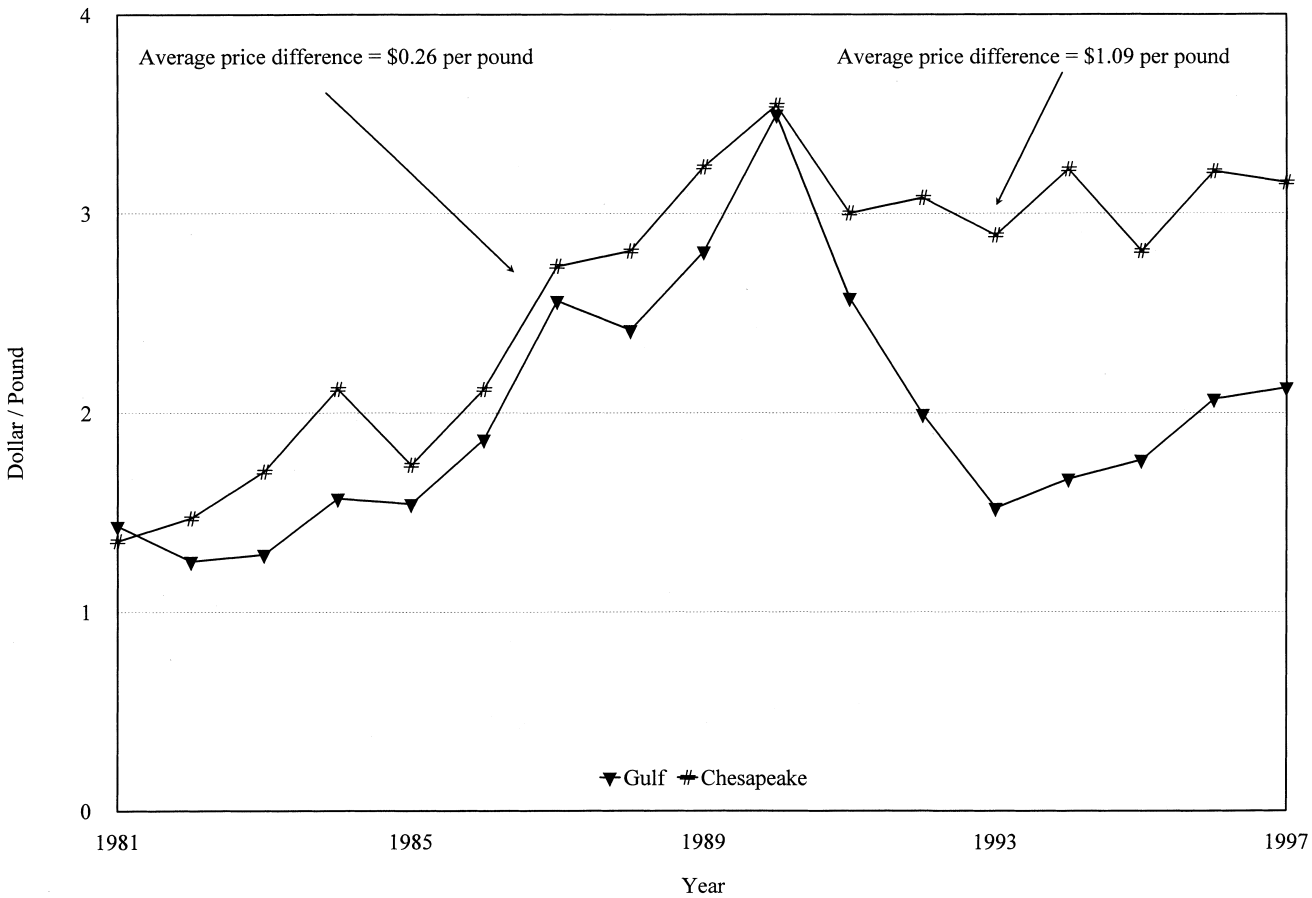

Figure 1.—Annual dockside oyster prices (current) in the Gulf and Chesapeake regions, 1981–97 (NMFS text footnote 2).

due to habitat degradation, overfishing, and disease (Rothschild et al., 1994). Then averaging close to 17 million pounds annually, the Chesapeake's output fell more than 90% to about 1.5 million pounds annually during 1995–97 (NMFS[2]).

Prior to 1991, annual dockside Gulf and Chesapeake oyster prices tended to "mirror" one another, with annual price differentials rarely exceeding $0.40 per pound (NMFS[2]) and an average price differential equal to only $0.26 per pound (Fig. 1). Since 1991, however, the prices in those regions have become decidedly more distinct, with the average annual price differential exceeding $1.00 per pound. The large price differential since 1991 provides some preliminary evidence that the mandatory warning labels and media attention may have impacted demand and, hence, price of the Gulf product.

Theoretical Basis and Literature Review

Strand (1999) reviewed the literature pertaining to consumer behavior with respect to food-borne contamination events, concluding that the information related to an event, which is subjectively evaluated by consumers, is critical to perception formation. He further suggested that uncertainty contained in the information can also be critical in perception formation. Finally, Strand suggested that the credibility of the information depends on its source.

Perceptions, of course, can alter consumer choice. Strand (1999) further concluded that consumers react to negative news by reducing demand for the product and/or by taking defensive actions to lower the level of health risk. Furthermore, as a result of uncertainty (e.g. uncertainty of the marketing channels through which they obtain their consumables), consumers may reduce demand even though there is no scientifically supported risk to them from normal consumption. Finally, Strand (1999) suggested that changes in demand owing to reports of persistent toxic compounds (like DDT) appear to be a reaction to cumulative news reports, and while the effects associated with news will decay over time, the decay is slow.

Strand's synthesis of the literature provides several insights that are relevant to this study. First, one might hypothesize that consumers have reacted to the negative publicity concerning the consumption of raw Gulf oysters by reducing demand for the raw product and/or taking defensive actions to lower the level of health risk. Such actions may include increasing demand for the processed product vis-a-vis the raw product or by reducing consumption only in the

"summer" months when health risks (in terms of mortality) from the consumption of raw oysters are greatest.

Second, uncertainty is likely to be a major factor in determining the change in demand for Gulf oysters. The uncertainty is inherent in both the information presented to the consumer as well as uncertainty presented to the consumer as to whether he/she possesses the health characteristics (i.e. liver disease, chronic illness, or a weakened immune system) that would make the consumption of raw oysters "risky."

Third, one could argue that the change in demand for Gulf oysters is analogous to Strand's (1999) discussion regarding changes in demand for food products resulting from reports of persistent toxic compounds. Specifically, while *Vibrio vulnificus* is not a toxic compound, like some such compounds, it is persistent in nature and continues to receive adverse publicity several years after the initiation of warning labels.

Model Specification

For purposes of analysis, the demand for Gulf oysters is specified as:

$$\begin{aligned} PG_t = \beta_0 + \beta_1 VUL_t + \\ \beta_2 SEAS_t + \beta_3 QG_t + \\ \beta_4 INC_t + \beta_5 (SEAS*VUL)_t + \\ \beta_6 (QG*SEAS)_t + \\ \beta_7 LATX_t + \beta_8 LPG_t + \in_t \end{aligned} \quad (1)$$

where PG_t denotes the deflated Gulf oyster dockside price in quarter *t,* expressed in dollars per pound of meats (1997 Consumer Price Index equals base); VUL_t is a binary variable used to "capture" the change in demand due to warning labels and associated media attention (equal to 0 before 1991 and 1 thereafter)[3]; $SEAS_t$ is a binary variable used to "capture" seasonality in the demand for Gulf oysters equal to 0 for the months April through September, (i.e. the 2nd and 3rd quarters) and 1 for all other months, (i.e. the 1st and 4th quarters); QG_t denotes the Gulf oyster harvest, expressed in millions of pounds of meats, in quarter *t*; INC_t denotes the U.S. real disposable income in quarter *t,* expressed in billions of dollars; $LATX_t$ denotes the share of Gulf oyster production accounted for by Louisiana and Texas in quarter *t*; LPG_t denotes the deflated Gulf price lagged one quarter; and $\in_t$ denotes the error term. Parameters to be estimated range from β_0 to β_8.

The equation, as specified, is price dependent. This reflects the fact that production in the Gulf tends to be determined, to a large degree, by the availability of oysters which, in turn, is largely dictated by environmental influences, particularly in the short run.[4]

The variable VUL_t was included to "capture" any decrease in demand associated with warning labels and media attention while the variable $SEAS_t$ was used to "capture" seasonal variation in demand. Since the incidence of *Vibrio* is temperature dependent and is higher in the warmer months of the year, it is further hypothesized that the impact of VUL_t may vary by season with the impact on demand being greater in the "summer" months. To account for the possible variation in impact by season, an interaction term between $SEAS_t$ and VUL_t is included in equation 1.

It is anticipated that price in quarter *t* responds inversely to changes in Gulf harvest (QG_t) and positively to changes in income (INC_t). Furthermore, given the interaction between harvest and season $(QG*SEAS)_t$, the response in price to a change in the quantity harvested is permitted to vary by season.

Louisiana and Texas, as noted, generally account for the majority of Gulf oyster production. There appears to be a premium attached to the price of oysters harvested from these two states, perhaps due to a larger average size. Hence, one would expect that the average Gulf price is positively related to the share of production derived from these two states. The variable $LATX_t$ is included in equation 1 to "capture" the price effect resulting from product heterogeneity across states.

The variable LPG_t is used to model inertia in the change in dockside price (PG_t) to changes in exogenous variables. The value of β_8 is expected to fall between 0 and 1 with a value approaching 0 indicating instantaneous adjustment in price to changes in the value of exogenous variables, while a value approaching 1 suggests a high degree of inertia.

Finally, substitute products are often entered as exogenous variables in demand models of this nature. One would hypothesize that oysters produced in other regions of the country might constitute substitutes for the Gulf product. Chesapeake oysters, given the similarity in the type of oyster produced and the geographic relation, were considered a potential substitute product, a priori. Initial inclusion of Chesapeake production in the Gulf demand equation did not prove to be successful and, hence

[3] While many studies which evaluate the impact of information on consumer demand quantify the amount of information available at regular intervals (Swartz and Strand, 1981; Johnson, 1988) or the amount of cumulative information (Brown and Schrader, 1990), the use of such procedures were, for several reasons, impractical with respect to the current study. First, the information is received from both warning labels and the print media, and any attempt to isolate these two factors would be problematic. Second, a large percentage of raw oyster consumption

[3] (continued) occurs in the away-from-home market, and much of the information appears to occur in trade journals. Hence, one would need to isolate the impact related to information in trade journals from that of the more common news media. Finally, most studies that have evaluated the impact of negative information on demand are based on products for which the duration was of only a limited period of time. With respect to the impact of *Vibrio vulnificus* on the demand for Gulf product, the publicity is of longer or continuing duration.

[4] A reviewer suggested that, because of leasing activities in Louisiana and Texas, quantity harvested may not be exogenous to the system. To examine this issue, a vector autogressive model between Gulf price (PG) and quantity (QG) was estimated as follows:

$$QG_t = \alpha_0 + \alpha_1 QG_{t-1} + \alpha_2 PG_t + \alpha_3 PG_{t-1} + \xi_{1t}$$
$$PG_t = \beta_0 + \beta_1 PG_{t-1} + \beta_2 QG_t + \beta_3 QG_{t-1} + \xi_{2t}$$

where QG_{t-1} represents the Gulf landings lagged one period and PG_{t-1} is the Gulf price lagged one period. The Gulf oyster price is said to be block exogenous with respect to Gulf landings if the elements in Gulf price are of no help in improving the forecast of Gulf landings based only on lagged values of PG. The null hypothesis is "PG is not exogenous to QG" which is equivalent to $\alpha_2 = \alpha_3 = 0$. The test statistic follows a chi square distribution with one degree of freedom. The associated chi square statistic of 0.01 (significance level is 3.84) at the 5% significance level implies that PG is not exogenous to QG. In contrast, the test statistic of 12.56 (significance level is 3.84) implies that QG is exogenous to PG. These results agree with the hypothesis that current Gulf landings contribute significantly to the improvement of the forecasted price based only on lagged prices. However, current and lagged prices do not statistically improve the forecasted landings based only on lagged landing values.

the variable was not included in the final version of the model discussed in the following sections.[5]

Data and Estimation Issues

Data Issues

The Gulf dockside demand model developed in the previous section was estimated with quarterly data for the 1981–97 period. Where appropriate (i.e. prices and income), the data were deflated using the 1997 Consumer Price Index. Some summary statistics for the variables included in the model are presented in Table 1. The deflated Gulf oyster price averaged $2.63 per pound, with the post 1990 price ($2.13 per pound) being nearly 30% less than the pre 1991 price ($2.98 per pound). The quantity harvested averaged 5.2 million pounds per quarter during the period of analysis, with the pre 1991 quarterly production (5.4 million pounds) averaging about 8% more than the post 1990 quarterly production (4.9 million pounds).[6]

In general, little price variation was evident during the 1981–97 period when examined on a seasonal basis, even though production during the "winter" season, which averaged 6.1 million pounds per quarter, exceeded the production during the "summer" season, which averaged 4.28 million pounds per quarter, by about 40%. Since 1991, "winter" season production has averaged 5.7 million pounds per quarter compared to 4.2 million pounds per quarter in the "summer" season.

Estimation Issues

The lagged dockside price (LPG_t), as noted, was included in the analysis, based on the premise that the response in price to a change in an exogenous variable may not be completed in that quarter in which the change in the exogenous variable occurred (i.e. there exists some inertia in the change in price). Assuming a geometric lag structure, this inertia, can be expressed as :

$$Y_t = \alpha + \beta\,(X_t + wX_{t-1} + w^2X_{t-2} + ...) + \in_t \qquad (2)$$

where w is the lagged weight ($0<w<1$) which declines at a geometric rate over time. As specified, equation 2 is difficult to estimate due to the infinite series of lagged regressors.

As shown by Madalla (1977) and Pindyck and Rubinfeld (1991), equation 2 can be rewritten as:

$$Y_t = \alpha(1-w) + wY_{t-1} + \beta X_t + (\in_t - w \in_{t-1}) \qquad (3)$$

Expressed in this manner, the geometric lag model can be easily estimated, given the finite series of the lagged variable (i.e. Y_{t-1}) .

The implications associated with equation 3 are twofold. First, all past values of the exogenous variable (X_t) are captured in the endogenous variable (Y_t) lagged one period with impact of a change in X_t on Y_t decaying at a geometric rate over time. Second, lagging the dependent variable results in the introduction of serial correlation of the error term, assuming $\in_t$ in equation 2 does not exhibit an autocorrelation pattern.

Several methods have been proposed for estimating the geometric lag structured model in the presence of serial correlation. The most popular technique, and the one that is used in the current analysis, is the instrumental variable approach whereby an estimate of the lagged dependent variable is generated by regressing its value against the lagged values of the exogenous variables in the model. Then, the model is estimated using a maximum likelihood procedure.

Given the structure of a geometric lag model, it is useful to identify the long-run impact associated with a permanent change in the level of an exogenous variable. Madalla (1977) shows that this impact is equal to $\beta/(1-w)$. Hence, as the value for w increases ($0 < w < 1$), the greater will be the amount of time which expires before the full impact of a one-time change in an exogenous variable is recognized. This, in turn, implies that the difference between the immediate impact (β) and long-run impact ($\beta/(1-w)$) increases in relation to an increasing value of the lagged weight (w).

Empirical Results

Table 2 summaries the regression results associated with the Gulf dockside demand model. The estimated parameters, in general, agreed with prior expectations and, with few exceptions, all estimated parameters were significant at the 90% confidence level. Furthermore, the estimated model explained almost 90% of the variation in the deflated Gulf dockside price (Table 2, Fig. 2).

Overall, increased information related to *Vibrio vulnificus* was found to significantly influence the demand (price) for Gulf oysters. Specifically,

[5] For comparison purposes, the model that includes Chesapeake production as an explanatory variable is included in the table that provides empirical results (Table 2).

[6] Much of the difference in pre and post 1990 production can be attributed to abnormally low production in Louisiana in 1991 and 1992. Low production in those years reflects massive oyster mortalities from excessive rainfall and, hence, lower salinity.

Table 1.—Summary statistics pertaining to the Gulf of Mexico oyster demand model.

Variable	Overall mean[1]		"Winter" mean		"Summer" mean	
1981–97						
PG ($/lb)	2.63	(0.81)	2.59	(0.83)	2.66	(0.80)
QG (Mill lbs)	5.20	(1.91)	6.11	(2.08)	4.28	(1.17)
INC ($ bill)	4,905.7	(588.0)	4,908.6	(593.3)	4,902.8	(591.6)
LATX (%)	0.77	(0.10)	0.74	(0.09)	0.79	(0.10)
1981–90						
PG ($/lb)	2.98	(0.82)	2.93	(0.87)	3.02	(0.79)
QG (Mill lbs)	5.38	(2.20)	6.40	(2.48)	4.36	(1.27)
INC ($ bill)	4,524.3	(442.2)	4,527.1	(447.8)	4,521.4	(448.1)
LATX (%)	0.76	(0.11)	0.73	(0.12)	0.78	(0.11)
1991–97						
PG ($/lb)	2.13	(0.46)	2.11	(0.44)	2.15	(0.49)
QG (Mill lbs)	4.94	(1.40)	5.71	(1.31)	4.16	(1.05)
INC ($ bill)	5,450.5	(228.6)	5,453.5	(238.3)	5,447.5	(227.5)
LATX (%)	0.78	(0.08)	0.75	(0.05)	0.81	(0.10)

[1] Standard errors of means are given in parentheses.

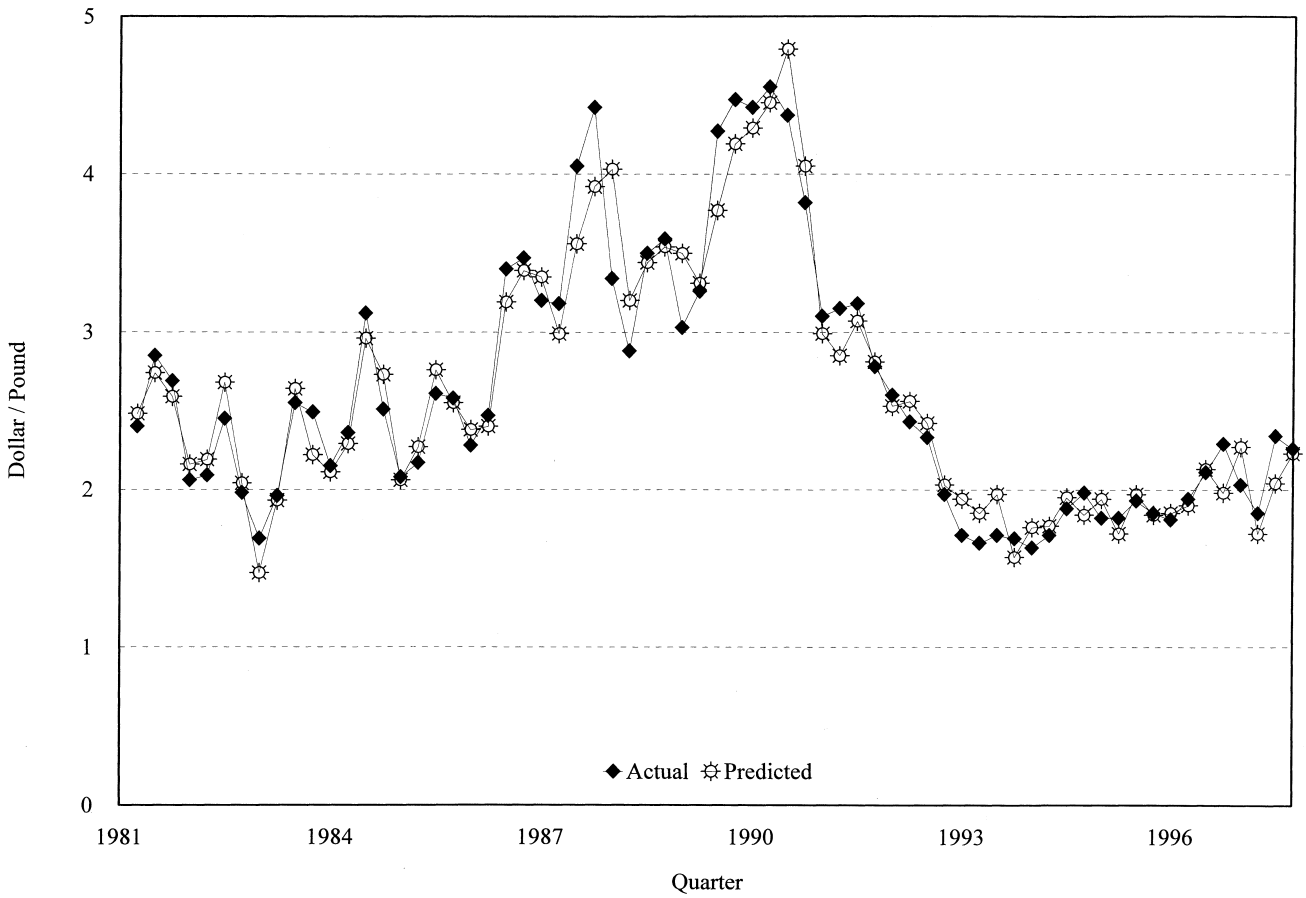

Figure 2.—Actual and predicted quarterly dockside Gulf oyster price (deflated), 1981–97.

the warning labels and associated media attention (VUL_t) resulted in an immediate reduction in the "summer" dockside price by $0.93 per pound compared to a reduction in the "winter" price of $0.72 per pound. These reductions, however, reflect only the initial impact. The fact that the estimate of β_8, equal to 0.553, falls between 0 and 1 implies that as one moves further away from the date that warning labels were initially mandated, the greater the absolute value of the magnitude of the policy variable.

In the long-run, the impact of warning labels was estimated to result in a decline in the "summer" dockside price equal to $2.07 per pound and a "winter" reduction in price equal to $1.60 per pound. The actual "summer" price in 1997 equaled $2.16 while the actual winter price equaled $2.22, suggesting that the "summer" price has been reduced nearly 50% as a result of the warning labels and negative publicity, while the "winter" price has been reduced by about 30%.[7]

Table 2.—Estimated parameters and standard errors associated with the Gulf of Mexico oyster demand model.

Variable	Estimated[1, 2] parameter	Standard error	Estimated[1, 3] parameter	Standard error
Intercept	0.669	0.537	0.349	0.606
VUL_t	–0.929*	0.174	–0.955*	0.175
$SEAS_t$	–0.624*	0.203	–0.741*	0.227
QG_t	–0.217*	0.036	–0.217*	0.036
QC_t			0.027	0.024
INC_t	0.372E-3*	0.134E-3	0.427E-3*	0.142E-3
$(SEAS * VUL)_t$	0.213**	0.114	0.299*	0.137
$(QG * SEAS)_t$	0.109*	0.036	0.111*	0.036
$LATX_t$	0.165	0.416	0.209	0.417
LPG_t	0.553*	0.076	0.557*	0.076

[1] * = statistically significant at the $\alpha = 0.05$ level; ** = statistically significant at the $\alpha = 0.10$ level.
[2] Model estimated without Chesapeake landings (QC_t) as an exogenous variable; adj. R^2=0.88.
[3] Model estimated with Chesapeake landings (QC_t) as an exogenous variable; adj. R^2 = 0.88.

[7] One could hypothesize that the impact of warning labels and the associated negative publicity

[7] (continued) decays at some rate with the passage of time as consumers either forget about the negative publicity or overcome initial fears. To examine whether this was the case, the analysis was also conducted for the 1981–93 period. In general, the parameter estimates varied only marginally (e.g. β_1 = –0.929 and β_5 = 0.265), suggesting that the decay in the initial impact is, at most, minor.

With respect to the Gulf landings (QG_t), the results suggest that a 1,000,000 pound increase (decrease) in "summer" harvest results in an immediate $0.22 decrease (increase) in price. An equivalent change in the "winter" harvest, by comparison, results in an immediate inverse price response of only $0.11 per pound, or about half of that estimated for the "summer" season. In the long-run, a 1,000,000 pound increase (decrease) in "summer" harvest was found to result in a $0.48 decrease (increase) in the Gulf dockside price, while a 1,000,000 pound increase (decrease) in the "winter" harvest was estimated to result in a price decrease (increase) of $0.24 per pound.

With respect to seasonality, the results suggest that the demand for Gulf oysters in the "winter" season exceeds demand in the "summer" season, with the expected price differential equaling about $0.07 per pound ceteris paribus, prior to 1991.[8] After 1991, in association with the warning labels and media attention, the difference in demand between the "winter" and "summer" seasons resulted in an expected price differential of $0.21 per pound.

Income, as indicated in Table 2, was found to significantly influence the Gulf oyster dockside demand. Overall, the results suggest that a $100 billion dollar increase in real disposable income would result in an immediate $0.04 increase in price and a price increase equal to $0.08 increase in the long run.

Discussion and Conclusion

A model was developed and analyzed to examine the impact of mandatory warning labels and the associated negative publicity on dockside price of Gulf oysters. Results suggest that the impact has been significant. Specifically, the results suggest that the "summer" price has been reduced by about 50% as a result of the warning labels and associated negative publicity, while the "winter" price has been reduced by about 30%.

The results developed in this paper can be used to assess the impacts of various policy measures. For example, the FDA, as noted in the introduction, proposed a restriction on sales of raw oysters for consumption from April to October when the *Vibrio vulnificus* bacteria is most prevalent in Gulf waters. From a welfare economics perspective, such a ban would lead to a net increase in the welfare of society if the benefits of taking action (i.e. prohibiting raw oyster consumption) exceed the costs. Benefits reflect, primarily, the reduction in premature deaths and illnesses. Costs, on the other hand, reflect the reduction in consumer and producer welfare (i.e. surplus) which would be incurred as a result of the ban.

As noted by Corcoran (1998), at least 10 people die annually from the consumption of raw Gulf oysters, while more than 50 become ill (an average of 17 individuals died annually during 1996–98). While assigning an economic value to a statistical life is problematic (Kuchler and Golan, 1999), recent empirical work, based on labor market analysis, suggests that the value of a statistical life, expressed in 1997 dollars, falls in the neighborhood of about $4–8 million (Viscusi, 1993, and Moore and Viscusi, 1988 provide details).[9] This suggests that the benefits from the proposed ban, excluding the reduction in illnesses, would approximate $40– 80 million annually.

An "upper bound" estimate of the loss in consumer welfare associated with such a ban can be generated under the assumption that production is equal to zero in those months that would be impacted by the proposed ban.[10] Based upon 1997 quarterly data and estimates, an "upper bound" estimate of the loss in consumer surplus in 1997 from the proposed ban would have been about $6,500,000 based on the 1997 dockside value of $21,200,000 (April through October).

While cost information on the Gulf oyster harvesting sector is insufficient to accurately estimate the loss in producer welfare associated with the proposed ban, it is obviously just a small fraction of the $21,200,000 in revenues generated during the April through October 1997 period. This fraction and the $6,500,000 loss in consumer welfare is considerably less than the $40–80 million annual benefits that would be forthcoming as a result of the ban. Hence, one could conclude that the welfare of society would be enhanced if the eating of raw Gulf oysters were seasonally restricted.

The FDA, as previously indicated, chose not to institute a ban on the consumption of raw Gulf oysters in the "summer" season, opting instead for a "public awareness campaign" to notify and educate those consumers at risk. As noted by Henson and Caswell (1999: 591), policy interventions by governments reflect an "...outcome of a complex trade-off between alternative demands that reflect the interests of the different groups that might be affected. In the case of food policy this will include consumers, food manufacturers, food retailers, and farmers, both at home and abroad, as well as government itself and taxpayers." Whether the alternative strategy (i.e. the awareness and education program), derived via this complex trade-off between alternative demands, proves to be as successful as a seasonal restriction would be has yet to be determined.

Acknowledgments

This research reported herein resulted from the Coastal Economy Strategy Development Project, conducted by Louisiana Sea Grant and partially funded by the U.S. Economic Development Administration, May 1998. The senior authorship is equally shared.

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[8] As indicated in Table 1, the observed 'summer" price exceeded the "winter" price by $0.05 per pound prior to 1991. Given the results of the current analysis, it appears as though the higher observed "summer" price reflects a lower level of production.

[9] The value of a life refers to the amount of money an individual is willing to trade for a small change in his or her probability of survival (Blomquist, 2001)

[10] Only an "upper bound" estimate of the loss in consumer welfare can be derived, because an unknown percentage of the "summer" season harvest is currently processed, which is not subject to the proposed ban. Furthermore, if the ban were to be implemented, the demand for processed product would likely increase resulting in a greater proportion of the harvested "summer" product being directed towards the processing sector.

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Vibrio vulnificus Infection: Diagnosis and Treatment

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Vibrio vulnificus infection is the leading cause of death related to seafood consumption in the United States. This virulent, gram-negative bacterium causes two distinct syndromes. The first is an overwhelming primary septicemia caused by consuming raw or undercooked seafood, particularly raw oysters. The second is a necrotizing wound infection acquired when an open wound is exposed to warm seawater with high concentrations of _V. vulnificus_. Most patients, including those with primary infection, develop sepsis and severe cellulitis with rapid development to ecchymoses and bullae. In severe cases, necrotizing fasciitis can develop. Case-fatality rates are greater than 50 percent for primary septicemia and about 15 percent for wound infections. Treatment of _V. vulnificus_ infection includes antibiotics, aggressive wound therapy, and supportive care. Most patients who acquire the infection have at least one predisposing immunocompromising condition. Physician awareness of risk factors for _V. vulnificus_ infection combined with prompt diagnosis and treatment can significantly improve patient outcomes. (Am Fam Physician 2007;76:539-44, 546. Copyright © 2007 American Academy of Family Physicians.)

▶ **Patient information:** A handout on *Vibrio vulnificus* infection, written by the authors of this article, is provided on page 546.

Vibrio vulnificus is a species of gram-negative, motile, curved bacterium that is part of the *Vibrio* genus and the Vibrionaceae family. Other members of this family include *V. cholerae* (rare in the United States) and *V. parahaemolyticus,* both of which cause acute gastrointestinal illness characterized by severe diarrhea. Unlike other members of this family, *V. vulnificus* infection is extremely invasive. Even with prompt diagnosis and aggressive therapy, the case-fatality rate is 30 to 40 percent.[1-3]

Epidemiology

V. vulnificus is common in warm seawater and thrives in water temperatures greater than 68°F (20°C). The organism is not associated with pollution or fecal waste. The taste, appearance, and odor of seafood are not affected by *V. vulnificus* contamination, and proper cooking methods readily kill the organism. Although it is found in all coastal waters of the United States, most *V. vulnificus* infections are attributed to consuming raw oysters harvested in the Gulf of Mexico during the summer.[2] Because these oysters are shipped throughout the United States, infections are not limited to endemic areas.[4]

Approximately 25 percent of *V. vulnificus* infections are caused by direct exposure of an open wound to warm seawater containing the organism. Exposure typically occurs when the patient is participating in water activities such as boating, fishing, or swimming. Infections are occasionally attributed to contact with raw seafood or marine wildlife.[1]

V. vulnificus is one of the few foodborne illnesses with an increasing incidence. The Centers for Disease Control and Prevention estimates that the average annual incidence of all *Vibrio* infections increased by 41 percent between 1996 and 2005.[5] In 2004, *V. vulnificus* was documented in 92 infections; 64 patients with the infection had septicemia, and 28 patients had wound infections.[1] These data emphasize the need for physicians to familiarize themselves with the risk factors and clinical characteristics of *V. vulnificus* infection.

Risk Factors

Table 1[2] includes risk factors for developing *V. vulnificus* infection. After the organism enters the body, several factors determine if significant illness develops. Patients with immunocompromising conditions, especially alcoholic liver disease or hepatitis B or C, have a higher risk of infection.[3]

SORT: KEY RECOMMENDATIONS FOR PRACTICE

Clinical recommendation	*Evidence rating*	*References*	*Comments*
Physicians should consider *Vibrio vulnificus* infection in patients with sepsis and severe skin lesions and should ask them about recent raw oyster consumption.	C	2, 12-14	Case series demonstrate high morbidity and mortality with *V. vulnificus* infection, and physician awareness is recommended.
Patients presenting with painful, rapidly progressive hemorrhagic bullae should receive prompt surgical evaluation for possible debridement.	C	20, 27, 28	Case series show a benefit from aggressive surgical management of necrotizing soft tissue infections.
Patients with chronic liver disease or immunocompromising conditions should avoid eating raw or undercooked seafood and open wound exposure to warm seawater.	C	4, 29, 30	Consensus guidelines

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, see page 483 or http://www.aafp.org/afpsort.xml.

Table 1. Risk Factors for *Vibrio vulnificus* Infection

Risk factor	*Patients with primary septicemia and the risk factor (%)*	*Patients with a wound infection and the risk factor (%)*
Consumption of raw oysters in the week before becoming ill	96	—
Wound exposure to warm seawater or raw seafood juice in the week before becoming ill	—	100
Any chronic disease	97	68
Liver disease	80	22
Alcoholism	65	32
Diabetes	35	20
Malignancy	17	10
Renal disease	7	7

NOTE: *Data are from the Centers for Disease Control and Prevention Gulf Coast Surveillance System.*

Information from reference 2.

Iron overload, documented by high transferrin saturation, is common in patients with liver disease and other immunocompromising conditions who develop *V. vulnificus* infection.[2] In human and animal studies, high levels of free iron have markedly increased the growth and lethality of *V. vulnificus*.[6,7] Patients with chronic liver disease have a much higher risk of septicemia and death; approximately 80 percent of deaths occur in patients with liver disease.[2]

Several characteristics of the organism facilitate the development of clinical disease. *V. vulnificus* strains with capsular materials are associated with high bacterial virulence.[8] In addition, *V. vulnificus* produces several extracellular enzymes, including metalloproteinase, lecithinase, lipase, caseinolytic protease, deoxyribonuclease, mucinase, and elastase.[9,10] Metalloproteinase destroys basement membrane collagen in blood vessels[10] and has fibrinolytic properties[11] that cause hemorrhage and edematous skin changes.

Clinical Presentations

Patients with primary septicemia caused by *V. vulnificus* infection require hospitalization. Characteristic symptoms include fever, diarrhea, nausea, and vomiting. One half of patients have changes in mental status, and almost one third are in septic shock at hospital admission.[12] Within 24 hours of symptom onset, more than one half of patients develop the characteristic skin lesions of severe cellulitis with ecchymoses and bullae.[12,13] *V. vulnificus* infection should be considered in patients with sepsis and severe skin lesions, and patients should be asked about raw oyster consumption and seawater exposure.[2,12-14]

Patients with primary wound infections caused by *V. vulnificus* develop painful cellulitis that progresses rapidly. Marked local tissue swelling with hemorrhagic bullae is characteristic *(Figure 1)*. Systemic symptoms include fever and chills.[12,13] Almost one half of patients develop bacteremia,[13,14] more

than 10 percent develop hypotension, and almost one third develop changes in mental status.[12]

Rarely, patients with *V. vulnificus* infection present with common gastroenteritis.[12] *V. vulnificus* infection should be considered in immunocompromised patients who have recently been exposed to seawater or consumed raw seafood.

Other presentations have occurred less often: infection of mucosal sites and corneal ulcers after handling seafood,[15] tuboovarian abscesses after sexual activity in seawater,[16] and peritoneal infection after receiving dialysis from seawater-contaminated equipment.[17] A high index of suspicion is required to diagnose *V. vulnificus* infection with these rare presentations.

Figure 1. *Vibrio vulnificus* infection presenting as edema; ecchymoses; and hemorrhagic, serous bullae on the lower legs.

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Illustrative Case

An 80-year-old man presented to the emergency department with excruciating pain in his right forearm. He reported spending the previous night fishing in Corpus Christi Bay (Tex.), where he accidentally pierced his right index finger with a live shrimp. Hemorrhagic bullae were present, extending from the hand to the upper arm. He also presented with confusion. His vital signs were a temperature of 100°F (38°C), blood pressure of 88/44 mm Hg, pulse rate of 113 beats per minute, and respiratory rate of 20 breaths per minute. The patient had a history of hypertension, chronic renal failure that did not require dialysis, congestive heart failure, and cirrhosis secondary to alcohol abuse. Laboratory studies revealed a white blood cell count of 6,600 per mm^3 (6.6×10^9 per L) with 26 percent bands, hemoglobin level of 13.1 g per dL (131 g per L), platelet count of 33,000 per mm^3 (33×10^9 per L), blood urea nitrogen level of 63 mg per dL (22.5 mmol per L), and creatinine level of 4.4 mg per dL (390 μmol per L). A Gram stain of the exudate showed a curved, gram-negative rod. Blood and wound cultures were obtained.

The patient was admitted to the intensive care unit and was treated with oxygen, fluid resuscitation, and intravenous ceftriaxone (Rocephin) and doxycycline (Doxy 100). Within six hours of admission, he required norepinephrine for blood pressure support. By the third day of hospitalization, dialysis was required because of worsening renal failure. On the fourth day of hospitalization, the patient markedly improved, answered questions appropriately, and no longer required pressor support. Wound culture confirmed the clinical diagnosis of *V. vulnificus* infection. After five days in the intensive care unit, he was in stable condition and was transferred to a local hospital.

Diagnosis

Table 2[18,19] presents etiologies for the differential diagnosis of aggressive soft tissue infection. Most of these infections involve a group A *Streptococcus* species or *Staphylococcus aureus.* Infections with necrotizing fasciitis are predominantly polymicrobial.[20,21]

At hospital admission, laboratory results of patients with *V. vulnificus* infection are indicative of severe bacterial infection, with a marked left shift in the white blood cell count. Renal injury with a rising serum creatinine level is common.[22] With severe

Table 2. Etiologies of Aggressive Soft Tissue Infections

Infection	*Patient history*	*Underlying conditions*	*Physical examination findings*
Group A *Streptococcus* species	Skin abrasion, trauma, recent herpes zoster infection, human bite, intravenous drug abuse	Diabetes, cancer, alcoholism, stasis dermatitis	Intense erythema, edema, lymphadenopathy, hemorrhagic and necrotic bullae
Staphylococcus aureus	Skin trauma, recent hospitalization or surgery, intravenous drug abuse	Obesity, diabetes, immunocompromising condition	Furuncles, local abscesses, diffuse macular erythroderma
Polymicrobial	Diabetic foot ulcer, recent surgery	Diabetes, immunocompromising condition, vascular disease	Moist gangrene with a foul odor
Pseudomonas species	Bacteremia, moist skin infection, severe burn, recent hospitalization	Immunocompromising condition	Hemorrhagic and necrotic bullae
Vibrio vulnificus	Exposure to raw or undercooked seafood or seawater	Liver disease, immunocompromising condition	Hemorrhagic and necrotic bullae, ecchymoses
Clostridium perfringens	Severe trauma with wound contamination, recent surgery, intravenous drug abuse	None	Pale skin, edema, hemorrhagic and necrotic bullae, foul-smelling discharge, gas formation
Pasteurella multocida	Cat or dog bite	None	Erythema, edema, serosanguineous discharge, lymphadenitis, tenosynovitis
Aeromonas hydrophila	Exposure to freshwater, skin abrasion	Usually none; sometimes an immunocompromising condition	Erythema, bullae, necrosis, possible gas formation

Information from references 18 and 19.

V. vulnificus or *Streptococcus pyogenes* infection, the creatine kinase level is often elevated when necrotizing fasciitis or myonecrosis is present.[23]

Radiographic studies (e.g., ultrasonography, computed tomography, magnetic resonance imaging) of affected tissues typically show nonspecific changes such as soft tissue edema and pockets of fluid. These findings may help exclude other conditions and guide aspiration attempts and the timing of surgical intervention.

Because sepsis is common, routine blood cultures should be performed when *V. vulnificus* is suspected. Bullae, ecchymoses, and abscesses are often productive sites to aspirate material for Gram stain and culture. In addition, Gram stain, culture, and frozen-section analysis of tissue is helpful to rapidly visualize bacteria and diagnose necrotizing fasciitis.[20] Additional cultures are guided by clinical symptoms and may include ocular, peritoneal, sputum, cervical, and stool cultures. Stool cultures require a thiosulfate citrate bile salts sucrose agar for isolation.[24]

Treatment and Prognosis

The recommended antibiotic therapy for *V. vulnificus* infection is doxycycline, 100 mg intravenously or orally (Vibramycin) twice a day; plus ceftazidime (Fortaz), 2 g intravenously every eight hours. Alternative antibiotic therapies are cefotaxime (Claforan), 2 g intravenously every eight hours; or ciprofloxacin (Cipro), 750 mg orally or 400 mg intravenously twice a day.[25,26]

In addition to antibiotics, many patients require aggressive supportive therapy in the intensive care setting. Aggressive and prompt wound care is essential. Surgical debridement; incision and drainage of abscesses; and, sometimes, amputation have been shown to reduce mortality and shorten

Table 3. Recommendations for Reducing the Risk of *Vibrio vulnificus* Infection

Avoid contact with raw seafood juices; use separate cutting boards and knives for seafood and nonseafood
Avoid eating raw oysters or seafood, especially if an immunocompromising condition or chronic liver disease is present; the risk is highest with seafood harvested in the summer
Cook shellfish thoroughly:
In the shell: boil until the shells open, then boil for another five minutes; or steam until the shells open, then steam for another nine minutes (do not eat shellfish that do not open during cooking)
Shucked oysters: boil for at least three minutes, or fry for at least 10 minutes at 375°F (191°C)
Promptly refrigerate leftover seafood
Wear gloves when handling raw oysters or shellfish
Persons with open wounds:
Avoid contact between open wounds and seawater, especially if water temperature is more than 68°F (20°C), or raw seafood
Wash any wound that is exposed to seawater with soap and clean water
Immediately seek medical care for any wound that appears infected

Information from reference 29 and 30.

hospitalization.[20,27,28] Patients presenting with painful, rapidly progressive hemorrhagic bullae should receive prompt surgical evaluation for possible debridement.[20,27,28]

V. vulnificus infections are commonly fatal, and the prognosis is directly linked to the speed and accuracy of diagnosis and treatment. When treatment was delayed by as little as 24 hours in patients with septicemia, mortality rates increased from 33 to 53 percent. Mortality rates increased to 100 percent in patients who were not treated within 72 hours.[12] Recent data show that when all types of *V. vulnificus* infections are combined, the overall mortality rate is 35 percent.[1]

Prevention

Table 3[29,30] includes recommendations for reducing the risk of *V. vulnificus* infection. Because *V. vulnificus*–related septicemia is usually caused by consuming raw oysters, most disease can be prevented by not eating this food. Limiting consumption of raw oysters to the winter months also can reduce the risk of infection. Patients with chronic liver disease or immunocompromising conditions are particularly vulnerable to infection and should be advised to avoid raw or undercooked seafood. Persons with open wounds should avoid contact with warm seawater.[4,29,30]

The authors thank Infectious Disease Specialist Colette Simon, MD, for her assistance with the preparation of the manuscript.

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Author disclosure: Nothing to disclose.

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Vibrio vulnificus Infection: What You Should Know

What is *Vibrio vulnificus* infection?

Vibrio vulnificus (VIB-ree-oh vul-NIF-i-cus) is a germ found in warm seawater. If you eat shellfish (especially oysters) or other seafood that has the germ, you can get an infection.

Who gets infected?

V. vulnificus infection is uncommon. Most people get it by eating raw oysters. If you have an open cut, you can get the germ by going in the ocean or touching raw seafood. You can't get it from other people.

What are the symptoms?

Most healthy people don't get sick even if they are infected. People with liver disease, kidney disease, or diabetes can get very sick if they are infected.

If you get sick from *V. vulnificus*, you might have a fever, vomiting, and diarrhea. You may also have redness, swelling, blisters, and bruising on your skin. If you have a cut, it could get infected.

What if I think I am infected?

Go to your doctor or the hospital right away. Do not wait because the infection spreads quickly.

Your doctor may test your blood or the blisters to tell if the infection is caused by *V. vulnificus*. Your doctor may give you medicine to stop the infection. Some patients need surgery.

How can I avoid getting infected?

Be sure to cook seafood thoroughly to kill the germ. Try not to touch raw seafood juices, and make sure to wash kitchen utensils in hot, soapy water.

If you have an illness that makes it more likely that you will get sick, avoid eating raw or undercooked seafood. If you have an open cut, you shouldn't do activities in seawater (for example, swimming, fishing, or boating).

Where can I get more information?

Your doctor

Centers for Disease Control and Prevention
Web site: http://www.cdc.gov/ncidod/dbmd/diseaseinfo (go to *Vibrio vulnificus*)

U.S. Food and Drug Administration
Web site: http://www.cfsan.fda.gov/~dms/vvfact.html

August 2007

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