
CHAPTER ELEVEN HUMAN HEALTH

Public health concerns arising from environmental management of Galveston Bay center on consumption of fish and shellfish harvested from the Galveston Bay, as well as from swimming or boating in polluted waters. Microbiological pathogens and toxicants are of primary concern. According to the Food and Drug Administration and the Center for Disease Control, 85 percent of illnesses resulting from seafood consumption in the past 10 years can be traced to raw shellfish (Billy, 1991). Because oysters feed by filtering enormous amounts of water through their bodies (100 gallons per day), they can absorb dangerous levels of contaminants from the waters. In addition, oysters are relatively immobile and are thus less free to move in and out of polluted areas. Contaminated oysters can threaten human health because they are often eaten raw without the protection provided only by relatively long cooking at high temperatures. Consumption of other fish and contact recreation present smaller hazards to human health, but are also considered in this chapter. The primary problem in protecting human health is a lack of resources for adequate monitoring and testing and for conducting longer-term studies about the effects of eating bay fish and shellfish on human health.

SHELLFISH

The Texas Shellfish Industry

It is difficult to determine the size of the Texas oyster industry since reporting of revenues is voluntary among oyster dealers and harvesters. Dealers may falsify records and underreport their sales in order to avoid a \$1 state tax placed on each barrel of oysters sold. As a result, state estimates of the Texas oyster industry may be underestimates of the actual revenues. Table 11-1 displays one agency's estimate. The decrease in landings is thought to result in large part from unusually heavy amounts of rainfall leading to higher loadings of fecal coliform between 1986 and 1990, rather than from any continuing trend in water quality or oyster availability.

Table 11-1
Oyster Landings, 1985 and 1990

Year	TEXAS		GALVESTON BAY	
	Landings (lbs.)	Value (000)	Landings (lbs.)	Value (000)
1990	1,925,400	\$5,982.00	1,165,654	\$4,092.10
1985	5,133,900	\$8,754.80	3,285,112	\$5,958.10

Source: Texas Parks and Wildlife Department.

However, bay industry harvesters complain that the size of their daily catches since the 1970s have been one tenth or less of the size of their catches in the sixties, and that it is only because of increased seafood prices that bay industry families have managed to survive (Sullivan, 1988). Indeed, a legislation scaling down the shrimping and finfishing industries has very likely resulted in the overharvesting of oysters. In 1976 the Magnuson Fishery Conservation and Management Act resulted in the closing of Mexican waters for fishing and shrimping for foreign vessels. This narrowed the Gulf waters available for shrimping and pitted bay shrimpers against gulf shrimpers. Regulations prohibiting taking of redfish have also forced finfishers to turn to shrimping, oystering, and crabbing. Redfish provided between 40 and 60 percent of a finfisher's income prior to the prohibition.

According to TPWD Code 76.102, a license to dredge oysters is not required from a boat already licensed as a commercial bay or bait shrimp boat. The data in Table 11-2 provided by TPWD indicate that the majority of oysterers are not accounted for by licenses. One can surmise that licensed shrimp boats partially account for the large amount of oyster landings shown in Table 11-1. The data also indicate that oysterers harvesting for sport number in the thousands each year.

Table 11-2
Licensed Oyster Dredge Boats and Bait Shrimp Boats
1980-1987

Fiscal Year	Commercial	Sport	Bait Shrimp
1980	178	4473	2016
1981	235	5215	2217
1982	218	4479	2283
1983	402	4711	2723
1984	323	4922	3103
1985	265	4387	2396
1986	243	3613	2680
1987	187	3327	1535

Source: Texas Oyster Fishery Management Plan (Series Number 1); Texas Parks and Wildlife, 1988, p. 96.

The importance of the large number of unlicensed, casual, or sport oysterers for human health is that these people are less likely to be aware of the complex regulations for gathering, storing, and, where appropriate, selling oysters than licensed commercial oysterers. As the number of oysters declines, moreover, these casual takers are more likely to be tempted by the large oysters that have grown undisturbed in areas closed because of pollution. Even when they eat the oysters themselves, resulting illnesses compromise the integrity of the entire industry.

Federal Context

In 1924, a typhoid fever outbreak in New York, Chicago and Washington, D.C. was traced to sewage-polluted oysters. The Surgeon General called a conference of state and municipal health officials. In 1925, they launched a nationwide program to monitor and regulate the distribution of shellfish for human consumption. The resulting program, called the National Shellfish Sanitation Program (NSSP), is a tripartite agreement among the federal government, state governments, and the shellfish industry.

Through the federal Food and Drug Administration (FDA), the federal government is responsible for making sure states conform to national guidelines for monitoring and ensuring the safety of consuming shellfish (USDHS and FDA, 1990). The FDA carries out its responsibilities by periodically inspecting shellfish processing plants, growing areas, and laboratories where water and shellfish samples are tested. The FDA also publishes a monthly list of valid interstate shellfish shipper certificates, which is used by state health officials and shellfish purchasers across the nation. In addition, the National Marine Fisheries Service (NMFS) conducts a voluntary seafood inspection program.

Twenty-four states that commercially produce shellfish have adopted the guidelines set forth in the NSSP Manual of Operations under state legislated laws. States, therefore, are responsible for conducting sanitary surveys of growing areas, delineating and patrolling restricted areas, inspecting shellfish plants, and issuing numbered certificates to shellfish dealers who comply with state sanitary laws. It is important to note that shellfish sanitation programs across the nation are controlled by state—not federal—laws. State governments pass laws based on NSSP guidelines and implement the programs, while the FDA checks each state's faithfulness to NSSP guidelines.

Industry members agree to comply to state shellfish sanitary laws. They also participate in the Interstate Shellfish Sanitation Conference (ISSC), which is comprised of state shellfish regulatory officials, FDA, and other federal agencies. Formed in 1982, the ISSC assists the FDA in administering the NSSP guidelines, promoting shellfish sanitation, adopting uniform procedures and developing comprehensive guidelines to regulate harvesting, processing and shipping of shellfish (U.S. Department of Commerce, NOAA, 1991). The ISSC also serves as an arbiter for grievances between the FDA, states and shellfish dealers, particularly if the FDA or the state threatens to remove the dealer from the

Interstate Certified Shellfish Shippers List. Removal from the list effectively renders the dealer's products unmarketable in any state. Grievances between the FDA and individual states, although rare, also occur and can be resolved through the ISSC procedure for unresolved disputes. Finally, the ISSC is responsible for updating the NSSP guidelines, with the FDA maintaining veto power over any changes. This veto power has not been frequently exercised.

In the past several years, consumers and the federal government have raised concerns regarding the national program. Between 1990 and 1991, Congress conducted a number of public hearings and introduced legislative proposals, which did not pass, to change or expand federal regulation of imported and domestic seafood. Congress gave FDA a \$9.5 million, or 38 percent, budget increase for its seafood inspection program. FDA is currently working on a report that would provide a "snapshot" of all state programs and shellfish sanitation activities. Due for release in early fall 1992, the report may uncover important differences in how states implement the NSSP guidelines, and how these differences undermine or improve the national effort. It is hoped that the study will shed light on the overall efficacy of the tripartite arrangement.

State Laws and Regulations

In Texas, the Division of Shellfish Sanitation Control (DSSC) in the Texas Department of Health (TDH) oversees human health aspects of the consumption and processing of aquatic life, crabs and shellfish under Chapter 436 of the Texas Health and Safety Code. The chapter, organized into three subchapters, authorizes the Division to monitor and ensure the safety of aquatic life (fish and shrimp), shellfish (oysters, mussels and clams), and crabs taken from Texas waters for human consumption.

Subchapter A gives the Division the authority to monitor aquatic life for contaminants that may affect human health. DSSC also is authorized to close polluted areas to commercial and recreational oystering, and license and monitor shellfish processing plants. Further, the Division is given latitude to adopt rules for the harvesting, transporting, storing, handling and packaging of shellfish and for the "efficient enforcement" of these rules. In effect, the law gives DSSC the authority to adopt the nationally accepted rules contained in the National Shellfish Sanitation Program (NSSP) Manual of Operations.

Within the same subchapter, the Division is granted the power to inspect shellfish processing plants at any reasonable time, issue or revoke licenses for these plants to operate, and certify or decertify the shellfish products made by these plants. The code specifies that all shellfish must be sold within a container bearing a valid certificate number. However, restaurants, among other entities, are exempt from this provision if the restaurant staff removes oysters from a certified container and sells the oysters at the same site. Selling shellfish when they are procured from prohibited areas is illegal even if they are in certified containers. DSSC may also seize or condemn any shellfish they deem unfit for human consumption. The transplanting of shellfish from polluted areas for artificial or natural cleansing is also governed by this subchapter. Finally, the subchapter gives the

Texas Department of Parks and Wildlife the exclusive power to enforce the closure of shellfish growing areas. The Division, with assistance from Parks and Wildlife, is given the authority to enforce the remaining parts of this subchapter.

As noted, the law has allowed DSSC to adopt the NSSP guidelines as regulations. The only substantial difference between the NSSP guidelines and state adopted rules lies in the classification system. The NSSP recommends a five-tier classification system (approved, conditionally approved, restricted, conditionally restricted and prohibited), but the state program is three-tiered (approved, conditionally approved and prohibited). Senate Bill 1463 in the 72nd Texas Legislature (1991-92) provided for a revision of definitions and a consolidation of some of the provisions of Section 436 of the Health and Safety Code, in addition to the elimination of the differences between the NSSP and the state program. This bill did not pass, but similar legislation making the state program consistent with the NSSP guidelines is likely to be introduced and passed in the near future.

Implementation

The Division of Shellfish Sanitation Control is responsible for surveying and classifying shellfish growing areas as to the suitability of such areas to produce shellfish fit for human consumption. The Division regulates shellfish harvesting areas primarily through the implementation of NSSP guidelines.

As noted, the Division employs a three-tier classification system: polluted, conditionally approved and approved. (Figure 11-1 on the following page shows the classifications of the Galveston Bay waters in 1991.) Harvesting from polluted waters is prohibited, except when the oysters are moved to less polluted private leases on Galveston Bay and allowed to "purify" themselves for at least 14 days. State health officials must then test the lease waters for bacteria levels before the oysters can be harvested. Approved areas are usually open for oyster harvesting, except during extreme weather conditions such as hurricanes or after disasters such as the 1990 oil spill near Red Fish Island. Conditionally approved areas are subject to closure based on environmental conditions monitored through DSSC's surveying process. Table 11-3 shows the designation(s) of shellfish harvesting waters for each of the major bay segments in Galveston Bay.

Table 11-3
Designated Shellfish Waters of Galveston Bay, 1991
(square miles)

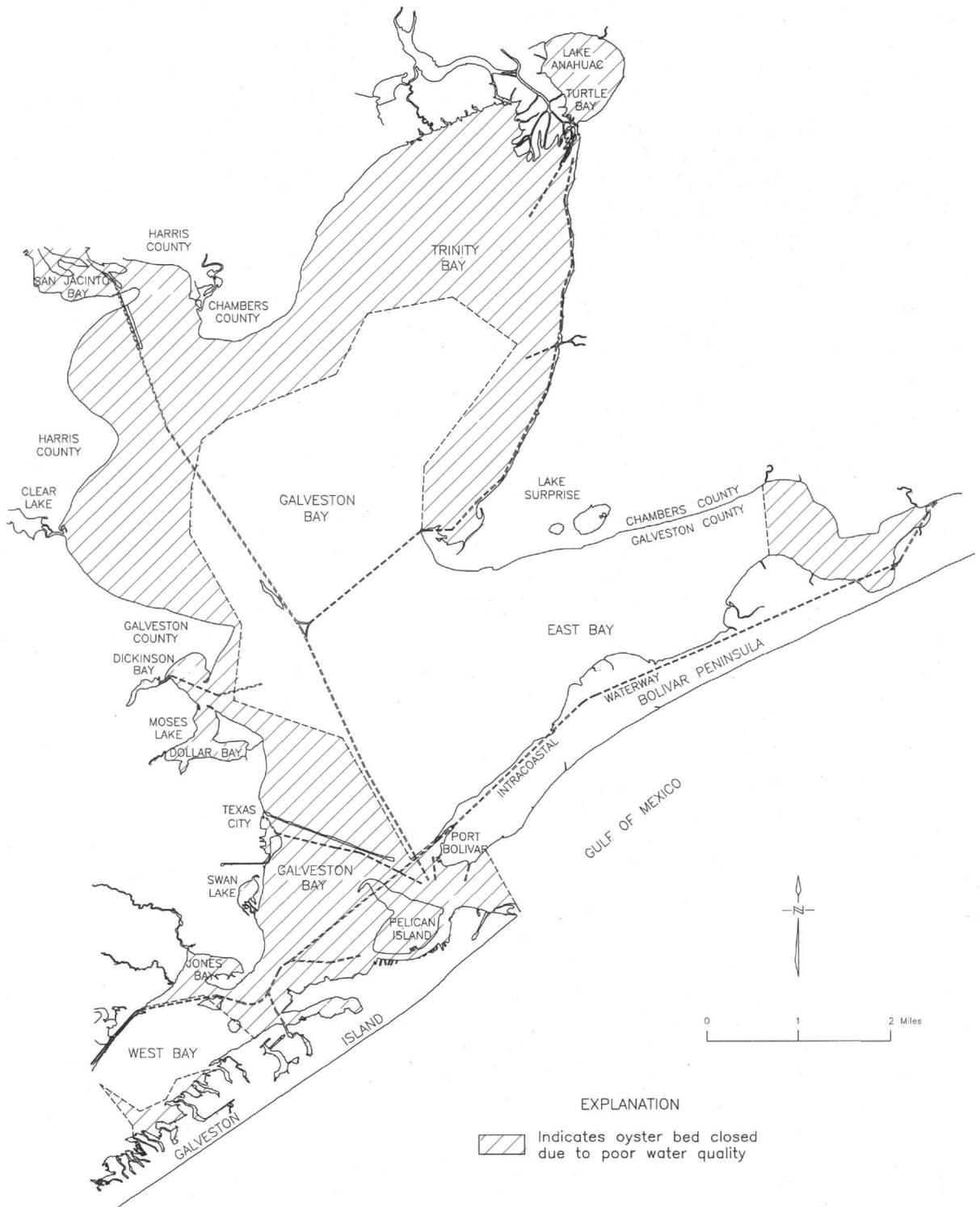
Segment	Bay Area	Approved	Conditiona l	Closed	Total
2421	Upper Galveston Bay	26.2	21.2	60.8	108.2
2422	Trinity Bay	22.5	25.9	81.7	130.1
2423	East Bay	39.4	0.0	12.7	52.1
2424	West Bay	45.9	0.0	23.4	69.3
2432	Chocolate Bay	0.0	0.0	7.6	7.6
2433	Bastrop Bay/ Oyster Lake	3.9	0.0	0.0	3.9
2434	Christmas Bay	8.9	0.0	0.0	8.9
2435	Drum Bay	1.7	0.0	0.0	1.7
2439	Lower Galveston Bay	79.3	8.5	51.8	139.6

Status: approved, conditional, closed.

Source: Texas Water Commission, State of Texas Water Quality Inventory, 1991, p. 21.

Figure 11-1

Areas Closed to Oyster Harvesting in Galveston Bay, 1991



Source: National Oceanic and Atmospheric Administration
(Estuary-of-the-Month Series)

Among the environmental problems associated with increasing population and shoreline development are erosion and bulkheading (see chapter 12), loss of wetlands and associated habitat (see chapters 6 and 9), subsidence related to increased ground water withdrawal (see chapter 12), degradation of water quality from both point and nonpoint sources (see chapters 3 and 4), and dredging for construction (see chapter 6). In short, shoreline development contributes to every one of the other. The process of classifying shellfish harvest areas involves conducting a growing area survey. The survey includes a determination of all actual and potential pollution sources (sewage treatment plants, residential, commercial and industrial developments, farms); a hydrographic survey (water dynamics, dispersion); a meteorological survey (quantity and frequency of rains, effects of winds); and a bacteriological survey (fecal coliform count). The results of the survey form the basis for classifying waters of the bay.

While all four components are used in determining the opening or closure of harvest areas in Galveston Bay, DSSC manages the bay on the basis of rainfall data gathered daily over the telephone from the National Weather Service, height of the Trinity River stage also collect daily from the National Weather Service, and bacteriological count, specifically of fecal coliform.

DSSC studies have shown that the fecal coliform count in the bay tends to exceed safe limits immediately after two or more inches of rain has flushed urban waste into the bay. Furthermore, excessive rainfall can cause sewage treatment plants to overflow or malfunction (TDH, DSSC, 1991a). The initial DSSC study used data from more than 7,500 bacteriological samples gathered between 1983 and 1987. In addition, annual reports since 1987 documents the correlation between rainfall and bacteriological count. When the height of the Trinity River exceeds nine feet at Moss Bluff, the Division closes Areas II and III (see 1991 classification map—Figure 11-1). The decision to use river stage is likewise based on statistical surveys carried out by the Division and confirmed in their annual reports on water quality.

Finally, and most importantly, the Division uses bacteriological data to manage the bay. Samples are taken from each of the more than 200 sampling stations set up in the Galveston Bay system, and is usually carried out by three staff people in the LaMarque field office in systematic "runs." Each run involves sampling from a set of stations designed to monitor conditions in a specific area of the bay during specific times of the year. When the entire bay is closed because of rainfall during winter, for example, staff members anticipate that the runoff flows southward from upper Galveston Bay through the Houston Ship Channel. In this case, the Division crew will sample a run that cuts east to west through the Galveston Bay from San Leon on the West to Smith Point on the East to see if the runoff and bacteria have moved past the bay system.

Between 25 and 29 samples are collected each day in 100 milliliter glass bottles that are stored in ice and sent to the LaMarque lab of TDH on the same day they are taken. Lab results are usually returned within 24 hours after the lab receives them or 28 hours after the first sample is collected. Bottles are numbered and dated; lab results are listed in the same order as the bottle number. The data are

then manually entered into a computer database. Field office staff generate weekly as well as annual reports from the database. Weekly reports are sent to the Austin office on a 5-1/4 floppy disk. No data has been lost so far, either in the computer system or in transport to the Austin office.

All samples taken from an area to be opened must register a fecal coliform count of 14 per 100 milliliters. In addition, 90 percent of all surrounding stations must show fewer than 43 fecal coliform per 100 milliliters (TDH, DSSC, 1991b, p. 15). Once these conditions are met, more samples are taken to confirm the results. During oyster season (November through April), DSSC buffers its decision to open with a waiting period of four days after the first sample collections. During off-seasons, the waiting period applicable for oyster leases, which operate year-round, is seven days. Frequent sampling and a long waiting period together counterbalance any single error in bacteriological results.

The presence of toxic dinoflagellates, which kill fish and shellfish and pose potential human health hazards to consumers, also would initiate bay closure through the Division's Biotoxin Monitoring Plan. The plan began in 1986 after a massive fish kill that devastated Galveston Bay tourism and fish industry. DSSC now periodically monitors these natural toxins during certain environmental conditions known to be conducive to higher levels of natural toxins, including warmer temperatures and high water salinity. The Division also relies on Parks and Wildlife and the Texas Water Commission, who are usually the first to be notified of large fish kills indicative of dinoflagellate "blooms"(TDH, DSSC,1991b). Once alerted of the possibility, DSSC tests both water and shellfish tissues for toxicity levels to determine closure and opening of affected bay areas.

Between September 28, 1967, and February 29, 1992, the Division closed parts or all of the Galveston Bay system for shellfish harvesting at least 65 times (TDH, DSSC Shellfish Orders). For 17 incidents of closure, mostly between March 1988 and November 1989, no reasons were cited. Of the 48 closures when reason was given, 42 were for "excessive rainfall"(TDH, 1991, p. 9). Other reasons included "adverse weather conditions," Hurricane Alicia, rain and runoff (three occasions) and an oil spill. Trinity Bay was closed 29 times during this period; Galveston Bay was closed 60 times; East Galveston Bay was closed 24 times and West Galveston Bay was closed 14 times. Closure periods ranged from one day to three months. Between June of 1988 and May of 1991, Area II of Galveston Bay was closed 32 percent of the time, while conditionally approved Area III located in Trinity Bay was closed 25 percent of the time. These figures include normal closure during summer months when oysters are not in season. It is important to note that closures do not necessarily reflect water quality trends in the Galveston Bay.

Work done in Galveston Bay is conducted by the LaMarque field office. Each year, field office staff updates the survey, summarizing the evaluation in an annual report. Every three years, the system of evaluating bay conditions is more thoroughly re-evaluated, and recommendations for change are made by the field office supervisor. Preparation of the reports is reserved for summer months when the bay is closed for oyster harvesting. Every twelve years, the Division revamps the entire classification and surveying system and conducts a comprehensive shore-

line survey of current pollution sources. The comprehensive survey also proposes an overall plan to manage shellfish harvest from the bay, based on the new data. Components of the twelve-year survey are much the same as the three-year survey; they include the pollution source survey, hydrographic survey, meteorological survey and the water quality/bacteriological analysis. DSSC conducted the last comprehensive sanitary survey in 1988 and the one before that in 1969 (TDH, DSSC, 1988).

In 1986, FDA started to review the Texas program because it was concerned that DSSC had fallen behind in conducting the comprehensive shoreline survey. The labor-intensive survey involves identifying all the residential and commercial developments, sewage treatment plants and their discharge volumes, industrial plants and their effluent discharge volumes, bird nests, farms and any other shoreline element having actual or potential impact on the water quality of Galveston Bay. FDA worked with DSSC to establish an action plan for overhauling the shellfish program and, according to FDA, found the Division's response to be "overwhelmingly positive." The Division used extra money appropriated by the Texas state legislature to gather and test increased numbers of water samples and produce the 1988 Comprehensive Sanitary Survey. The problem seemed to stem from inadequate resources rather than a lack of will.

Analysis of Implementation

Overall, the use of rainfall data, river stage data and bacteriological counts seem to be both statistically valid as well as convenient tools for managing the harvesting of shellfish from the Galveston Bay system. The two-inch rule for rainfall and the nine-foot river stage criteria are backed by several years of bacteriological statistics that used a significant number of samples. The threshold for fecal coliform level is set by the nationally recognized NSSP manual. However, there are four areas of concern or contention in shellfish monitoring and closure:

Fecal coliform as indicator. The first is the validity of fecal coliform as an indicator of pollution and disease. The disadvantage of using the fecal coliform indicator is that the test registers fecal coliform from both human and animal feces (the latter being less harmful to human health). A station located in relatively less polluted waters near a heron rookery, for example, may register high levels of fecal coliform generated by heron feces. Another disadvantage is that fecal coliform is an indirect indicator of harmful pollution, bacteria or viruses. An alternative indicator is *Escherichia coli*, which is specific to human feces. Direct indicators involve testing both waters and shellfish tissues for harmful viruses, i.e. hepatitis A. These alternative tests are extraordinarily expensive, and while they are better than the fecal coliform test, they presently do not seem to be cost effective.

V. vulnificus, a virulent bacterium. The second issue involves DSSC's inability to test and set predictable standards for a particularly virulent strain of bacteria called *Vibrio vulnificus*. The bacteria are naturally present in most gulf and warm bay waters, but in varying concentrations. Between 1981 and 1991, 53 cases

of *V. vulnificus* infections, either from consuming raw shellfish infected with the bacteria or direct exposure, were reported (Morgan and Guthrie, 1991). The fatality rates for *V. vulnificus* infections range from 50 to 69 percent (U.S. FDA and DHHS). Little is known about the bacteria except their affinity for warm water containing high levels of salinity. Their ubiquitous presence in both prohibited and approved waters is a cause for concern for health officials. DSSC currently has no systematic way to prevent *V. vulnificus*-infected oysters from reaching the market.

In an effort to remedy this gap, the FDA in conjunction with the EPA and several Gulf of Mexico states are conducting field studies to establish a continuous monitoring system that can act as an early warning when *V. vulnificus* levels become high. Furthermore, health officials hope the studies will help them to develop an understanding of the specific environmental conditions such as water salinity, temperature and nutrient load, that influence growth of the bacteria in water or shellfish (FDA, 1991).

Public information. The third issue involves informing the public of openings and closures of the bay to shellfish harvesting, as well as of the health risks of consuming certain seafood products. DSSC uses several media outlets to announce closure or opening of the shellfish growing areas. Classification maps are made available at the DSSC field offices, including the LaMarque and Austin offices, and Parks and Wildlife Department locations where people purchase fishing and hunting licenses. Changes in status of bay waters are also announced via the National Weather Service radio channel and a 24-hour telephone recording. Although the Division issues press releases regarding fish and shellfish consumption advisories, it does not purchase newspaper or television ads due to budget constraints. Seafood consumption advisories are, however, published in the Texas Parks and Wildlife Fishing Guide.

While these methods of information dissemination reach all seasoned commercial oyster harvesters and fishers, they have not been completely effective at reaching recreational harvesters and sports fishers, many of whom come from out of town. While commercial harvesting far outweighs recreational harvesting, the health risks apply equally to both situations, and the growing number of part-time and casual oysterers exacerbates the problem. Budget and staff constraints, which will be discussed later in detail, prevent DSSC from employing more effective media outlets such as local newspaper and television advertisements and participating in civic and neighborhood group discussions.

Certification of processing plants. The criteria used by DSSC to inspect and certify shellfish processing plants have been a matter of debate. Oyster dealers who process oysters purchased from independent harvesters contend that enforcement of the criteria vary by inspector. This is because NSSP criteria set forth in the Manual of Operations, Part II, are open to some interpretation. One example is the requirement that oyster shipments are made in mechanically refrigerated conveyances, such as trucks, maintained at or below 45 degrees Fahrenheit (U.S. DHHS, 1990). Oysters just harvested from warm waters, purchased by a dealer and placed in refrigerated truck compartments for interstate transport often take

several hours to cool down to 45 degrees Fahrenheit. Meanwhile, the shipment could be confiscated because it does not meet the NSSP temperature criterion. Just as enforcement of NSSP criteria differ from inspector to inspector, enforcement can also vary from state to state, creating possible economic advantage to dealers and harvesters in states where regulations are less strictly enforced.

Time and temperature regulations. Ensuring the healthfulness of shellfish requires that the shellfish are kept in certain conditions once they are harvested. Under current laws, DSSC does not regulate the amount of time oysters are kept by harvesters, nor do they regulate the conditions under which they are kept en route to dealers. Thus, oysters could be kept in warm weather conditions for eight or more hours before they reach refrigeration (dealers are required to move oysters to refrigerated compartments within two hours after receipt). During this time, bacteria and viruses such as salmonella and hepatitis A could spread and reach levels dangerous to human health if consumed. This gap is labeled by health officials as time/temperature abuse.

If DSSC were to require that all oysters be stored on ice immediately after harvesting, which would reduce risks posed by improper storage, many independent fishers would probably be put out of business since large ice chests represent a significant capital investment and large ice purchases a major operating cost. An alternative approach would be to require boats planning to harvest on warm days to register with dealers beforehand at a certain time. These boats would be required to return to the same dealer before a certain time, say within four hours after registering, to sell all oysters harvested thus far. They would then be allowed to harvest for another four hours.

The federal Food and Drug Administration is developing a comprehensive review of all state shellfish sanitation programs and growing areas under its 1991-1992 Seafood Plan in an effort to compile a national "snapshot." The survey may reveal important differences in the way states implement NSSP guidelines. The Seafood Plan also calls for the development of time and temperature requirements for harvest, transport and storage of shellfish. Once developed, these requirements may be adopted by states to remedy existing gaps within the current NSSP guidelines.

Enforcement

While the Division of Shellfish Sanitation Control is responsible for classifying shellfish growing waters, updating and distributing maps delineating approved areas, and inspecting shellfish processing plants, the Texas Parks and Wildlife Department (TPWD) is responsible for enforcing harvest area closures. Under an agreement signed by the Texas Department of Health and TPWD on December 29, 1964, TPWD retains the authority to patrol shellfish growing areas in Galveston Bay to prevent the harvesting of oysters and shellfish from closed waters (Peavy and Watson, 1964). TPWD also has the authority to apprehend and prosecute people violating the restrictions under Article 965 of the Texas Penal Code.

The Texas City TPWD Office has jurisdiction over the 533 square miles of Galveston Bay as well as 245 shoreline miles. The office is staffed by 20 game wardens. The area is patrolled by 15 game wardens on any given day. As many as 200 to 400 oyster boats are out harvesting when the Bay system is open. While it is obvious that wardens cannot constantly monitor the activities of every boat, two factors need to be considered in evaluating the enforcement of bay closures. The first is cost effectiveness; an additional warden, while helpful, may not significantly expand Parks and Wildlife's enforcement capabilities enough to justify the cost. Second, game wardens receive cooperation from citizens who alert wardens of illegal harvesting in prohibited waters. Harvesters who are either concerned about public health or do not want other harvesters to gain an advantage through their access of illegal oysters also notify wardens.

One of the most effective ways of discouraging illicit harvesting is through dealers, who can refuse to purchase oysters harvested from prohibited waters. Dealers often know when harvesters are trying to sell catches culled from prohibited waters. Boats that illicitly harvest from prohibited waters at night often show up on dealers' docks early in the morning. Also, oysters culled from prohibited waters are substantially larger, muddier and more algae-ridden than oysters from approved waters. This is because oysters in prohibited waters are usually left alone and, therefore, allowed to grow much larger than their approved counterparts. Cooperation from industry members is critical to the successful enforcement of the state shellfish sanitation program.

Because of the difficulty of patrolling the bay at night, TPWD has made harvesting oysters from 30 minutes before sunset to 30 minutes after sunrise illegal. Nevertheless, most violations occur in the evening when most wardens are not actively patrolling the bay. According to game wardens, an oyster boat can cross over to closed waters, cull 300 pounds of oysters and cross back into open waters in one-and-one-half to two hours. Occasionally, game wardens would receive phone calls in the evening from waterfront residents reporting violations. By the time wardens can drive to the boathouse in Texas City and launch a boat, 45 minutes usually elapses. This estimate does not include the time it would take to locate violators in evening darkness.

A number of other duties compete for the attention of TPWD game wardens. Because TPWD is concerned with conservation and species propagation, wardens check harvested oysters to make sure at least 80 percent of those inspected measure three or more inches. The process of checking oysters, writing citations and preserving evidence can take between one and four hours per boat. Game wardens are also responsible for checking safety equipment of recreational boats in the bay and checking fish catches to make sure they conform to fishing restrictions. During the fall and winter, wardens appear to place their highest priority on enforcing shellfish area closures and oyster conservation. During the summer months when Galveston Bay is more heavily visited, wardens must monitor boating safety (i.e. sober boating and children wearing life jackets). Since oystering is closed during the summer months except to lease holders, this does not seem to pose a substantial enforcement problem.

TPWD has worked with the Division of Shellfish Sanitation Control to lobby county judges and the state legislature to increase penalties for harvest violations and to move cases more quickly through the judicial system. During its 1989 session, the state legislature increased oystering in closed waters from a Class C to a Class B misdemeanor; the penalties were raised accordingly to a maximum fine of \$1,000 with up to six months jail time from \$500 maximum penalty and no jail time (Fortney, 1991). Should harvesting in closed waters occur at night, the crime is raised to a Class A misdemeanor with a maximum fine of \$2,000 and up to one year in prison. Second offenses also constitute Class A misdemeanors, and third offenses become a Class III felony with up to ten years of jail time.

This change has created two side effects. On the one hand, arrests have substantially decreased in Galveston, Chambers, and Harris Counties bordering the Galveston Bay system. As Table 11-4 shows, there was a dramatic decrease in arrests following passage of the new penalties. This is an imperfect indication of the level of industry cooperation or harvester compliance with bay closures since game wardens may simply choose to make fewer arrests. However, this possibility is unlikely; game wardens seem to be well trusted by community leaders and health officials who interact with the wardens almost daily. Also, there is a possibility that "bootleggers" may be more careful or clever because of the stiffer penalties, thereby more effectively eluding wardens. More than likely, however, the decrease in arrests roughly reflects a lower rate of closed water violations and a higher level of cooperation from industry members.

Table 11-4
Arrests for Violation of Oyster Rules

Year	1987	1988	1989	1990	1991
Arrests	201	311	184	31	14

Source: Texas Parks and Wildlife Department

A second development is the increase in the number of cases being litigated in county courts. Since the fines are greater, harvesters find it more worthwhile to fight the charges rather than to pay the fine (Whitlow, 1991). In Calhoun County, oyster violation cases are backlogged by one year. Similar backlogs are evident in the three counties surrounding Galveston Bay.

Parks and Wildlife wardens have difficulty proving in court borderline cases where harvesters are just inside the closed area line. Lines delineating closed, approved and conditionally approved areas are set from landmark to landmark. Because no actual lines are drawn along the waters, harvesters may plead ignorance in court, saying that the demarcations are vague. Wardens and harvesters alike say, however, that nearly all harvesters know within five yards where the lines are. Judges and juries have displayed less leniency toward offenders after penalties increased in 1989, making this a less effective defense.

TPWD wardens work closely with DSSC officials in determining lines that can be enforced. They prefer permanent markers that cannot be easily removed such as oil drilling platforms, piers and tide gauge pilings. Should the markers be removed, harvesters can legally cull across any lines once demarcated by the missing marker. Game wardens and health officials have been careful in choosing relatively immovable markers and actively maintaining them.

In short, Parks and Wildlife game wardens present an effective deterrence program short of monitoring every oyster vessel on the bay. While this does not constitute a watertight program that prevents all oysters from closed waters from reaching the market, it does significantly reduce the likelihood that polluted oysters will be harvested.

Inter-Agency and Industry Cooperation

Any program where one agency is primarily responsible for implementation and another for enforcement may be compromised by lack of coordination. In this section, we review cooperation among the agencies. We also consider industry cooperation, which, as with all other programs in an area as large as Galveston Bay, is essential to long-term protection of the environment.

As noted, the most important form of inter-agency cooperation is DSSC's relationship with the Texas Parks and Wildlife Department. Established in 1964, this critical link provides the shellfish monitoring program with the enforcement of bay closures. While the Division classifies shellfish growing areas, Parks and Wildlife maintains the responsibility of patrolling the growing areas, preventing the harvest of shellfish from closed areas, issuing citations to violators and arresting violators when necessary.

According to Parks and Wildlife game wardens, DSSC promptly contacts both Parks and Wildlife and commercial oyster harvesters to warn of changes in bay classification. This is done to minimize confusion caused by an overlap in the times in which each party is notified of an opening or closure. For example, should harvesters be notified thirty minutes before Parks and Wildlife game wardens of the bay's opening, wardens unaware of the opening during the thirty-minute gap may mistakenly arrest a harvester for culling in what wardens may think is closed waters. Since DSSC strives to notify all parties at the same time, such confusion is usually avoided.

The two agencies also work together to determine enforceable lines between growing areas. They also have joined forces to successfully lobby the state legislature to increase the penalties for harvesting in closed waters. The combined lobbying effort also involved persuading county judges to take such violations seriously in considering oyster harvesting offenses. The relationship is extended further when health officials appear several times out of the year as expert witnesses during Parks and Wildlife prosecutions of offenders.

DSSC also receives water quality and sewage/industrial discharge information from the Texas Water Commission. The Commission, however, uses a metal

filtering method for calculating fecal coliform levels, which does not conform to FDA standards. The Division uses the air bubble method, which is in compliance with the federal standards. While information on discharge and pollution sources is important to the Division in developing its sanitary surveys, the relationship with the Water Commission is less close than with TPWD. Finally, DSSC also cooperates with the federal Food and Drug Administration. In addition to monitoring the Division's shellfish sanitation program, FDA provides the Division with technical advice, such as developing lead and arsenic standards and conducting studies on *V. vulnificus*.

Industry cooperation is critical to the success of the shellfish monitoring program. Dealers may refuse to purchase oysters that may have come from prohibited waters or report boats that fish in closed waters. Some dealers voluntarily comply with regulations because they believe doing so would yield a safer product. As one dealer said, "One bad oyster could ruin the industry." Early in 1992, negative media coverage of a single county's oysters caused sales to drop considerably, and California required that all Texas oysters be noted as suspect. Thus product safety and healthfulness are effective selling points, and Texas' strong shellfish sanitation program is an asset. This symbiotic relationship, however, applies almost exclusively to established oyster dealers with long-term leases and heavy capital expenditures who have a stake in the industry's reputation and long-term health.

Shrimp dealers who take up oystering during winter months when shrimp are not in season tend not to be as cooperative or concerned with product safety. Communicating with and soliciting comments from industry fishermen on important health related issues can be difficult because the industry is so loosely organized. The Professional Involvement of Seafood Concerned Enterprises (PISCES) is the only trade association representing bay industry interests on legislative and other issues. The Texas Shrimp Association represents primarily the gulf industry. PISCES was very active in trying to prevent the prohibition on redfish and speckled trout harvesting in the bay. Due to the absence of any pressing issues that directly affect the bay industry, PISCES has become much less active of late.

Evaluation

Among public health problems, consumption of contaminated shellfish probably ranks low in numbers of people affected and high in visibility and drama. Moreover, this public health problem may harm an entire industry, even when caused by unlicensed or casual oysterers. The means for minimizing the problem include demarcating areas where oysters may not be collected, requiring that processors be licensed and inspected, and imposing fines on fishermen operating illegally.

Like controlling nonpoint source pollution, protecting public health requires many dispersed individuals to cooperate in taking actions whose payoffs accrue to people other than themselves. It is impossible for any agency to delineate accurately all the areas where oysters should and should not be collected, inform

everyone who needs to know about these areas, and ensure that no one violates the rules for collecting, storing, and transporting shellfish. The system that is in place appears to be reasonably effective, despite some important gaps concerning public information, use of indirect indicators for identifying contaminated areas, and certifying processing plants. Those with the largest stake in the system, the commercial oysterers, are most likely to comply.

In addition to refining the time and temperature rules and making the other incremental changes suggested above, two other programs might decrease the risks of becoming sick from eating contaminated oysters. First, a public education campaign encouraging people to eat only cooked oysters could help reduce problems caused by fecal coliforms. Even in seafood restaurants, the staff might suggest to diners that "We recommend the cooked oysters rather than the raw ones". However, such a program does run the risk of leading people to believe that a little cooking will always be adequate to eliminate bacteria, when this is not in fact the case.

A second refinement would be to develop means for discouraging casual commercial oysterers. It would be entirely unrealistic to think that individuals will cease collecting oysters for their own use. However, processors could offer lower prices to those without a commercial oyster license, or could refuse to purchase from them altogether. Other means for internal policing of the industry might be equally effective. In short, we are suggesting that creative use of market mechanisms or economic incentives could further strengthen a system that seems to be working reasonably well, but where the payoff for adding further regulatory resources would seem to be relatively low.

FISH

The regulatory framework for ensuring that fish are safe to eat is similar to that for oysters. Testing procedures are governed exclusively by state laws. At present, there are no FDA regulations addressing pollution levels for fish consumption. In Texas, as for shellfish, the Division of Shellfish Sanitation Control (DSSC) in the Texas Department of Health (TDH) oversees human health aspects of the consumption and processing of fish under Chapter 436 of the Texas Health and Safety Code. Subchapter A gives DSSC authority to monitor aquatic life for contaminants that may affect human health. It may prohibit fishing in waters it finds too polluted. Violation of the ban can result in a fine of \$200 to \$500 and seizure of the fish or shrimp catch.

However, health problems and regulation of fish differ in significant ways from oysters. With the exception of fish that have not been properly stored, the human health effects from eating contaminated fish are usually long-term and subtle, in contrast to the immediate effects of eating bad oysters. The contaminants of concern are heavy metals and other substances that accumulate in the tissues of the fish and may also accumulate in human tissue. Furthermore, fish are mobile, while oysters are largely immobile. Whereas it is possible to guess about the safety of an oyster from testing the water around it, it is necessary to test the fish itself. Each fish may be different, so a relatively large number of fish must be

tested before authorities can reasonably decide whether to warn the public about fish consumption.

The core of the safety program is therefore fish samples that are analyzed for various contaminants. Based on these samples, DSSC identifies potentially polluted waters. However, there are many constraints on its ability both to sample and to use samples to make policy decisions. As a result, DSSC has limited its action to releasing a general health advisory against consuming more than eight ounces of fresh and saltwater catfish and blue crabs per month if they are taken from waters in Upper Galveston Bay or the Houston Ship Channel because of dioxin. Pregnant women and children are advised against consuming any catfish or blue crabs from Texas. One fish kill occurred due to a spill of vinyl acetate from a barge at the loading dock, affecting about two miles of the Bayport Channel (TWC, 1992, p. 16).

Problems with fish testing for contamination fall into two categories: lack of scientific information and lack of laboratory resources. Among the gaps in underlying scientific data is a lack of information needed to establish maximum levels allowable in fish of lead, cadmium, and arsenic—substances whose accumulation in human tissues may lead to serious health effects at some time in the future. Although it is not clear how much, if any, of these substances humans can tolerate, FDA hopes to release suggested standards for them in the 1991-92 Seafood Plan. Even more uncertainty characterizes scientists' understanding of effects of combinations of toxics. Some chemicals are rendered harmless when combined with another neutralizing chemical, but others may be triggered by the presence of a catalyst chemical. To make definitive judgments regarding fish consumption would require extensive laboratory studies over a long period to determine human health effects of exposure to varying amounts of toxic substances in fish, followed by testing and analysis of a statistically significant number of fish samples. Quite apart from the lack of basic health information, testing fish tissues for toxics is often expensive: for example, it costs \$2,000 to test one fish sample for the presence of dioxin.

A more immediate problem is the scarcity of laboratory and testing resources. DSSC currently uses all its allotted lab resources for both tissue and water testing, and could not test for additional contaminants even if FDA does provide suggested standards. Testing for mercury alone would require four days of lab time for a maximum of seven samples. Even monitoring for *V. vulnificus*, mentioned in the discussion of oysters as a serious if rare health problem, would require an expansion of the current level of testing. DSSC tailors the number of sample crews to the amount of lab time they have; it would be useless to gather more samples than can be tested.

DSSC attempts to overcome the laboratory bottleneck by sharing information with other agencies. As in other cases, however, differences in agency mandates undermine the utility of other agencies' information. For example, DSSC uses its fish samples to determine possible human health effects, while Parks and Wildlife is primarily concerned about species propagation.

DSSC also participates in the Fish Contamination Subcommittee of the legislatively mandated state Toxic Coordinating Committee. Established in 1990, the subcommittee is comprised of eight government entities, including Texas Parks and Wildlife, the Railroad Commission, Texas Department of Agriculture, General Land Office, U.S. Fish and Wildlife Service, the Environmental Protection Agency, the federal Food and Drug Administration, and DSSC. The Fish Contamination subcommittee meets monthly to discuss the need to test fish for trace metals and contaminants harmful to human health. Since DSSC currently lacks the funds necessary to conduct a comprehensive fish sampling and testing program on its own, such interagency cooperation enables the agency to expand its role into monitoring aquatic life without extra state funding. Benefits of the inter-agency arrangement flows from two sources: shared information and direct federal grants.

Through the subcommittee, DSSC found a forum for communicating with related agencies. Participating agencies share sampling information, coordinate sampling and testing activities to avoid duplication of effort, and devise an agreed-upon standardized fish sampling protocol. Member agencies are currently participating in a project to combine sampling efforts and characterize toxic contamination in the Trinity River. In addition, DSSC received \$3,500 from FDA and \$48,000 from the EPA in FY 1991 to conduct fish sampling and testing and develop brochures that would inform the public of the hazards of consuming fish from certain Texas waters, including the Galveston Bay. With these funds DSSC was able to test 450 fish samples. DSSC is currently drafting a new public fish advisory list and brochure.

The entire area of health effects from fish consumption is characterized by uncertainty: uncertainty about the nature and extent of human health effects from varying levels of residues in fish tissues and uncertainty about ways of identifying affected fish. The expense of testing, combined with these uncertainties and the serious limits on laboratory resources, has created a program that is limited in extent. While Texas may wish to conduct some research on human health effects, a more immediate approach would be to characterize the waters of Galveston Bay for toxic "hot spots" and ambient levels and to attempt to correlate this information with a systematic sampling of fish from several different areas. Without this information, any requests for significant increases in laboratory resources would be premature. Meanwhile, residents of the bay area should be cautioned to eat a diversity of fish and to avoid known hot spots during recreational fishing.

CONTACT RECREATION

In addition to eating bay seafood, people may come into direct contact with bay waters through swimming or, more likely, boating. As Table 4 in chapter 8 (shoreline development) shows, more than half the people living in the 4-county area surveyed for a recent GBNEP study said they swim in the bay. The Texas Water Commission establishes water quality standards for both contact and non-contact recreation. As with shellfish, fecal coliform is the primary indicator for

water quality; 200 colonies per milliliter are allowed for swimmable waters, and 2000 for boatable waters.

County health departments take water samples and have the authority to post areas commonly used for boating or swimming if they do not meet these standards. For sampling purposes, the bay is divided into districts and specific sites are sampled one to three times a month depending on their history as a problem site. Time often does not allow for widespread sampling. For example, the Galveston County Health Department has two full time staff responsible for sampling in excess of 60 sites at least one per month. Moreover, samples can only be taken when laboratory personnel (also very limited) are available for testing and even then the sample often expires before it can be analyzed. Because of these constraints, health officials tend to sample the same site several times and to concentrate on problematic areas such as the storm drains emptying off the bay and gulf sides of Galveston Island.

County officials interviewed were of the opinion that pollution due to inflow and infiltration during rainfall is a chronic problem in the entire bay area. Ground shifts are common in the area and cause sewer pipes to break or flow in the wrong direction. When rainfall seeps in, it overflows the system and raw sewage ends up in the bay. County officials are reluctant to repair pipelines because of the expense and because breaks and leaks could recur again at any time.

Sites known to be polluted are rarely posted by either county or state officials. TDH has the authority to post warning signs in polluted areas but rarely does so because it is not involved in sampling recreational waters for pollution. One official at TDH commented that "the state has never really had a program for testing waters for swimming;" at the same time, TDH is expressly mandated to supply information to people inquiring about harvesting. Conversely, while TWC conducts some sampling, it does not have the authority to post polluted areas, and it typically does not share sampling results with TDH. Some officials expressed concern that if they begin posting areas that are polluted, they may be held liable if someone contracts a disease in an area that is not posted; the costs of posting are also high. Nevertheless, legislation allowing TWC to post polluted areas should be considered.

Perhaps the most effective means for reducing the (unknown) human health effects of contact recreation is to teach schoolchildren some common sense rules. During the swimming and boating safety programs offered by most schools, teachers could also discuss polluted water and the dangers of swimming or boating in it. Avoiding obvious outfalls from storm sewers and municipal and industrial plants and not swallowing water while swimming are two simple rules that most children can understand. More aggressive posting of contaminated areas by local health officials would remind people of lessons learned in childhood.

EVALUATION

All too often in the past, environmental programs used human health as the yardstick for measuring environmental degradation or as the standard for protection without considering effects on species that might be even more sensitive than humans. In this way, for example, certain pesticides were approved that seriously harmed fish and birds. However, protecting human health is also an important environmental goal. In Galveston Bay, the two goals converge: if various sources of pollution, particularly point and nonpoint source fecal coliforms but also heavy metals and other toxic substances, were reduced, human health would be less at risk.

Everyone we spoke to cautioned that it is not correct to infer water quality from the mere fact of a shellfish closure. Other reasons, including administrative concerns about delimiting an area or enforcing in it, may also contribute to a closure. Moreover, the water quality criterion for shellfish is very strict because oysters are filter feeders; indeed, the criterion for shellfish closure is stronger even than for contact recreation. Thus closed areas may be relatively safe; open areas are guaranteed to have extremely good water quality.

In the meantime, specific programs for reducing human health problems focus most strongly on shellfish, especially oysters, which lend themselves to regulation both by their immobility and by the dramatic effects of eating bad ones. The system for protecting human health is to use water quality as an indirect indicator of oyster safety; there are some questions about the effectiveness of the indicators, which may overstate the risks in some cases and understate them in others. Inspection and licensing of facilities that handle oysters and fish are intended to reduce post-harvest contamination. Fish also present possible long-term human health concerns if they are contaminated with residues of heavy metals and other toxic substances; unfortunately, the scientific basis for determining when fish should and should not be consumed is mostly lacking. Limited facilities for testing of both fish and water affect the quality of regulation both of fish and of swimmable and boatable waters.

Because risks to human health are so diverse, reducing them requires several different approaches. We believe that the most effective approach overall is to focus on sound environmental protection; human health risks will be reduced as environmental quality improves. Recognizing that people may be more willing to devote resources to reducing human health risks than to ecological protection, however, we also suggest that it would be useful to develop ways in which sampling and testing protocols could be used to serve both purposes, allowing different agencies to use their limited resources to fulfill not only their own mandates but also to help other agencies as well. By expanding and consolidating present efforts at sharing information, agencies can make the whole regulatory effort total more than the sum of its parts.

SUMMARY EVALUATION: HUMAN HEALTH

1. **Problem.** Consumption of seafood contaminated with various pollutants because of poor water quality harms human health, restricts harvests, and limits possibilities for contact recreation. In Galveston Bay alone, oysters, the shellfish most commonly implicated in human health problems, are worth \$6 million annually. Fish in the bay are exposed to a number of toxics such as lead, cadmium, and arsenic that may accumulate in the human body for years with unknown health effects.

2. **Authority.** Following federal guidelines of the National Shellfish Sanitation Program, the Division of Shellfish Sanitation Control (DSSC) in the Texas Department of Health monitors water quality and aquatic life, closing waters that are too polluted for safe shellfish catch. TWC establishes water quality standards for contact and non-contact recreation.

3. **Capacity.** FDA inspects shellfish processing plants, growing areas, and laboratories where shellfish samples are tested. 20 Parks and Wildlife game wardens for 2-400 oyster boats. Enforcement acceptable to satisfactory. 450 fish samples tested in 1991, which seems low considering the variety of fish and diversity of locations.

4. **Policy.** Various indicators of safety are used, including fecal coliforms and others. Rainfall data are also important, since heavy rainfall causes more runoff containing contaminants. Closures are frequent. County judges reluctant to fine violators.

5. **Technical and environmental results.** A few human health incidents annually. Unknown level of exposure from low-level fish toxics, contact recreation.

6. **Barriers and problems.**

- a. \$1 state tax per barrel of oysters leads to underreporting (to avoid tax) which increases the difficulty of oversight of landed oysters.
- b. Health problems yield bad publicity which hurts whole industry.
- c. Time and temperature regulations apply to landed shellfish, not on boats.
- d. Many sport fishermen unaware of constantly-changing closures.
- e. Over-reliance on fecal coliform as indicator, inability to test for vibrio.
- f. Inconsistencies in certification of processing plants.

7. **Recommendations.**

- a. Teach people to cook shellfish rather than eating them raw.
- b. Add time and temperature regulations: in hot weather, boats may register the time they leave and must return in 4 hours to be able to sell oysters.
- c. Develop means for informing the public about closures and the consequences of ignoring them.
- d. Increase testing and monitoring. Research on long-term effects of fish consumption.

REFERENCES

- Billy, Thomas J. Director, Office of Seafood. Food and Drug Administration. Remarks during the International Seafood Conference. Luxembourg, October 9, 1991.
- Division of Shellfish Sanitation Control. Comprehensive Sanitary Survey of the Producing Waters of Galveston Bay. Texas Department of Health. Austin, Texas, June 1988.
- Division of Shellfish Sanitation Control. DSSC 1991 Annual Report. Texas Department of Health. Austin, Texas, 1991.
- Division of Shellfish Sanitation Control. Re-evaluation of the Comprehensive Survey for the Shellfish Growing Areas of Galveston Bay: Annual Report, Texas Department of Health. Austin, Texas, August 1, 1991.
- Food and Drug Administration and the U.S. Department of Health and Human Services. Get Hooked on Seafood Safety. Washington, D.C. (Pamphlet)
- Food and Drug Administration. FY 91-92 Seafood Plan. Washington, D.C., 1991.
- Fortney, Paul. "Oyster Processors Claim Dispute Ruining Their Business." Austin American-Statesman. November 17, 1991, p. B14.
- Morgan, Garth R., and Rufus K. Guthrie. Vibrio Growth in Oysters from Different Processing Stages. School of Public Health, The University of Texas Health Science Center at Houston, March, 1991.
- National Oceanic and Atmospheric Administration. The 1990 National Shellfish Register of Classified Estuarine Waters. U.S. Department of Commerce. Washington, D.C., July 1991.
- Peavy, J.E., and J. Weldon Watson. "Agreement on Cooperative Procedures for Administering and Regulating the Sanitary Control of the Shellfish Industry by the Texas State Department of Health and the Texas Parks and Wildlife Department." Austin, Texas, December 29, 1964.
- Sullivan, Kathleen. We'll work 'til We Starve: Work and Politics in the Inshore Fisheries - Galveston Bay. Professional Report. LBJ School of Public Affairs, The University of Texas at Austin, 1988.
- Texas Department of Health, 1991 Annual Report. Austin, Texas, 1991.
- Texas Department of Health, 1991 Annual Survey. Austin, Texas, 1991.
- Texas Department of Health, DSSC Shellfish Orders. Austin, Texas.

Texas Water Commission. State of Texas Water Quality Inventory. Austin, Texas, April, 1992.

U.S. Department of Health and Human Services. National Shellfish Sanitation Program Manual of Operations Part II. Washington, D.C., 1990. (Revised Edition)

U.S. Department of Health and Human Services, Public Health Service, and Food and Drug Administration. National Shellfish Sanitation Program Manual of Operations, Parts I and II. Washington, D.C., 1990. (Revised Edition)