Chapter 2

THE POTENTIAL FOR RECREATIONAL SHELLFISH HARVESTING ALONG THE BRICKYARD SHORELINE

Mirtha Ninayahuar

The State Department of Parks and Recreation presently regards the Berkeley Brickyard (FIGURE 1) as a prime site for the first phase of a proposed East Bay Shoreline Park. The purpose of this report is to examine the potential for safe recreational shellfish harvesting in this area with respect to the following points: (1) the suitability of shellfish resources for recreational harvesting; (2) the levels of major contaminants in the shellfish; (3) the public health standards affecting the possible establishment of recreational shellfish harvesting. Two shellfish beds exist along the Brickyard shoreline, one at the end of Bancroft Way (FIGURE 1, bed #15) and the other at the end of University Avenue (bed #16). In an attempt to determine the possibility of recreational harvesting in this area, I will review and summarize shellfish studies dating from 1970 to 1981 performed in or around the Brickyard area, and present results of tests conducted for this study.

Species of shellfish studied are those most abundant and popular with recreational harvesters of the San Francisco Bay. These include the Japanese littleneck clam (*Tapes japonica*), the softshell clam (*Mya arenaria*), and the bay mussel (*Mytilus edulis*). Consideration is given to the following contaminants: bacteria, viruses, paralytic shellfish poison, trace metals, and synthetic organic compounds (i.e., pesticides). The quality of water overlying the shellfish beds will be touched upon only briefly, as Aaron Jeung's report entitled "Water Quality Management Along the East Bay Shoreline Area" evaluates the water quality around the Brickyard.

Introduction

Just before the turn of the century San Francisco Bay was a rich source of shellfish for commercial and recreational harvesters. The bay supplied most of California's shellfish used in trade (RWQCB, 1978). Up to 15 million pounds of oysters were harvested from the bay each year (Vandre, 1980). Pollution after the

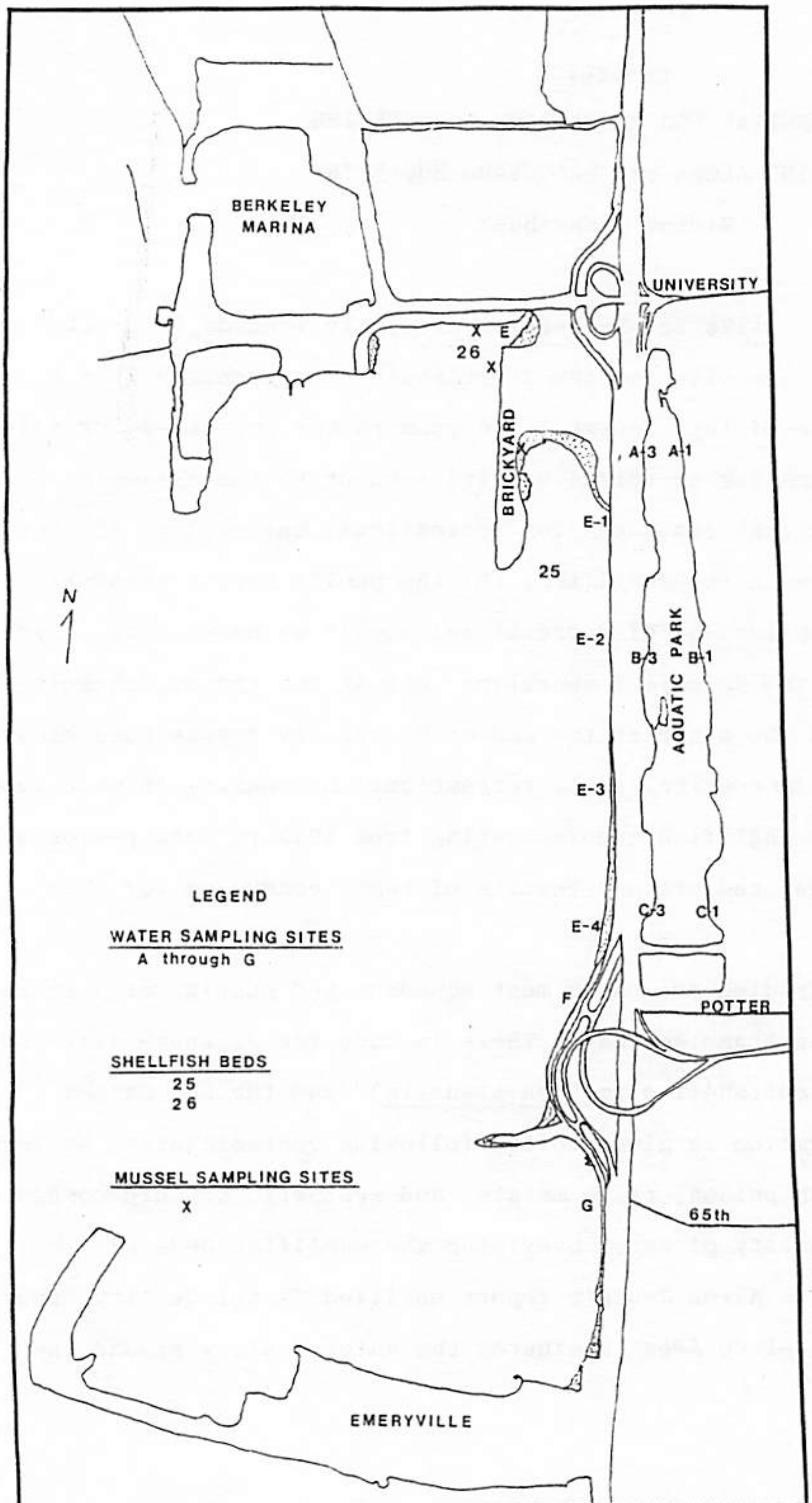

FIGURE 1. Sampling Site Locations.

Source: Water Sampling Sites, Sharpe, 1977.
Shellfish Bed Locations, Jones and Stokes, 1977.
Base Map, USGS Topographic Map: Richmond, 1968; Oakland West, 1973.

1900's caused the ultimate closure of all commercial shellfish operations, as well as the sharp decline of recreational harvesting. California presently has an annual mussel quarantine between May 1 and October 31 which prohibits the harvesting of all mussel species along the coast and in all bays, inlets, and harbors (Jones and Stokes, 1977). Aside from this, recreational harvesting is legal; however, it is not recommended by state and county health agencies. Certain shellfish beds have been posted as being unsafe due to high levels of contaminants, but these postings are only warnings and are not enforced to prevent recreational harvesting. Currently limited and uncontrolled recreational harvesting occurs in the bay without any assurance as to the quality of shellfish harvested (RWQCB, 1978). In a 1981 survey for the East Bay Municipal Utility District, sections along the Brickyard shoreline were rated as areas being moderately exploited for shellfish, while areas nearby, such as the south end of the Berkeley Marina, were rated as being heavily exploited (Sutton, 1981). Of all the shellfish collectors along the East Bay shoreline that were interviewed in Sutton's study, more than half indicated that they used the shellfish for food.

The restoration of safe shellfish harvesting depends largely on the efforts to clean up the bay. Since 1974 approximately $,750,000 has been committed for wastewater treatment specifically to protect shellfish (RWQCB, 1978). Portions of these funds have been used for adding advanced secondary treatment facilities to wastewater treatment plants, as well as for extending outfalls farther away from shellfish beds (Jarvis, pers. comm., 1982).

In 1978, the Regional Water Quality Control Board (RWQCB, San Francisco Bay Region) adopted a resolution (No. 78-8) to achieve the opening of San Francisco Bay shellfish beds for recreational use. The goal of the RWQCB Shellfish Program includes determining the factors and conditions that may affect the safety of an area for direct recreational harvesting, what periodic monitoring would be needed to detect adverse changes in water quality and shellfish safety, and what additional control of point and nonpoint sources of contamination can be accomplished to minimize closing of an area. The Regional Board is coordinating the Shellfish Program with the help of the State Department of Health Services, the Department of Fish and Game, the Bay Conservation and Development Commission, the Environmental Protection Agency, the Association of Bay Area Governments, and the State Water Resources Control Board. Most of the Regional Board's work is being conducted in the south bay as the shellfish beds in this area are of highest priority. Priority was based on shellfish populations, public use, and public access. Shellfish beds

#25 and #26 along the Brickyard shore are not among the ten shellfish beds studied by the Shellfish Program. The program, directed by marine biologist Fred Jarvis, is presently investigating sources of contamination to shellfish beds in order to determine cost-effective management practices needed to eliminate or reduce the contamination of beds by dry weather drainage.

Suitability of Shellfish Resources for Recreational Harvesting

According to the Department of Fish and Game, an area with a shellfish population of about 500,000 is suitable for recreational harvesting. The most current population surveys performed in the Berkeley Marina, which includes the Brickyard, have shown the shellfish populations to be stable at around 400,000. TABLE 1 gives a summary of shellfish population surveys along the East Bay shore.

Date of Survey	Estimated Bed Size (ft^2)	Location	Tapes	Mya	Other	Total	Source[b]
1968	22,800	Bed 25	42,960	48,600	---[a]	91,560	1
1972	800	Bed 26	0	8,000	---	8,000	1
1972	---	Bed 25	$11/m^2$	$27/m^2$	---	---	2
1972	1,134	Berk. Marina	24,948	61,236	---	86,184	2
1977	63,000	Bed 26	422,100	50,400	---	472,500	1
1980	54,300	Berkeley	209,000	11,600	225,300	445,900	3
1980	85,950	Berk. Marina	$12.8/ft^2$	---	---	1,103,765	3
1980	54,300	Berk. Marina	$3.8/ft^2$	---	---	225,300	3
1980	6,943	Bed 25	96,750	---	---	108,300	2
1980	1,776	Bed 25	---	11,550	---	11,550	2
1980	14,854	Berk. Marina	276,000	27,600	---	303,600	2

a = data not reported

b = Source: 1 - Jones and Stokes, 1977
2 - Sutton, J., 1981
3 - McAllister and Moore, 1982

TABLE 1. Summary of Shellfish Population.

It should be noted that none of the surveys include bay mussel populations, even though the southern half of the Brickyard shoreline is densely populated by them.

From the recent population estimates given in TABLE 1, it can be concluded that the shellfish resources appear to be suitable for recreational use. However, factors such as recruitment and mortality rates, as well as the effect of increased harvesting, need to be studied in order to manage the present shellfish resources properly for recreational harvesting purposes.

Shellfish Standards

The quality of shellfish consumed by the public is of great concern to health agencies for three main reasons (Sharpe, 1977): (1) shellfish as filter feeders may concentrate bacteria and viruses up to 100 times and chemical contaminants up to several hundred times the values in overlying waters; (2) shellfish are often eaten raw or partially cooked; (3) the entire animal including stomach and digestive tract is consumed. Many problems exist in determining the acceptable levels of toxic contaminants in shellfish for human consumption, as the health effects of these contaminants depend on many factors, such as the consumer's physiological state of health, and frequency and quantity of species ingested (DOHS, no date). Some contaminants are not measurable with present laboratory techniques. This is the case for some viruses, such as the agent of infectious hepatitis. The lack of toxicological data has limited the number of established standards.

The U.S. Public Health Service has developed bacterial standards governing the harvesting of shellfish. These standards are based on measuring levels of total and fecal coliform bacteria in shellfish and shellfish-growing waters and using such data to indicate the potential presence of pathogenic bacteria (Cooper et al., 1981). To enumerate the number of coliform present, ten-fold dilutions of the sample are planted in a series of tubes of specialized media. The distribution of positive tubes among the dilutions can be related statistically to the number of coliforms present in the original sample, the Most Probable Number (MPN) (Cooper et al., 1976). TABLE 2 gives the coliform bacteria MPN standards set for shellfish-growing waters and shellfish meat.

The Food and Drug Administration (FDA) establishes levels for poisonous and deleterious substances in human food. Action levels are defined as those limits at or above which the FDA will take legal action to remove contaminated products from the market (Dept. of Fish and Game, 1982). TABLE 3 lists the FDA action levels for identified pollutants in shellfish.

As can be seen from TABLE 3, mercury is the only heavy metal which has a set concentration limit. However, the FDA has set alert limits for five other heavy metals found in shellfish, the softshell clam in particular. Alert levels are intended to be used as an indicator of growing area degradation due to pollution

Bacterial Standards for Shellfish-Growing Waters

The coliform median MPN shall not exceed 70/100 ml, and not more than 10% of samples shall exceed 230/100 ml, for a 5-tube decimal dilution test or 330/100 ml where a 3-tube decimal dilution test is used.

Fecal coliform median MPN of the samples shall not exceed 14/100 ml and not more than 10% of the samples shall exceed an MPN of 43 for a 5-tube decimal dilution test or 49 for a 3-tube decimal dilution test.

Bacterial Standard for Shellfish Meat

Shellfish are not considered for interstate commerce unless fecal coliform MPN is 230/100 grams of meat.

This standard is used only as a supplement to growing water standards.

TABLE 2. Bacterial Standards.
Source: Cooper *et al.*, 1980.

Substance	Action Level (ppm fresh weight)
mercury	1.0
aldrin/dieldrin	0.3
endrin	0.3
heptachlor and heptachlor epoxide	0.3
kepone	0.3
PCB	5.0

TABLE 3. FDA Action Levels for Identified Shellfish Pollutants
Source: Dept. of Fish and Game, 1982

and do not imply toxic levels in shellfish meats. Alert levels also sttempt to set concentrations above which further investigation and consideration from a public health point of view may be warranted (Bradford and Luoma, 1979). TABLE 4 lists FDA alert levels for heavy metals in softshell clams.

Metal	Alert Level (ppm wet weight)
Cadmium	0.5
Chromium	5.0
Copper	25.0
Lead	5.0
Zinc	30.0

TABLE 4. FDA Alert Levels for Heavy Metals in Softshell Clams.

Source: Jones and Stokes, 1977.

General Summary of Shellfish Contaminants

The following section is devoted to the review and summary of available data on the levels of contaminants in the shellfish in or around the Brickyard area. These contaminants include bacteria, viruses, paralytic shellfish poison, trace-metals, and synthetic organic compounds (i.e., pesticides). Contaminant levels are compared to the established or recommended tolerance limits from which one may infer the potential for safe consumption of these shellfish.

It must be kept in mind that studies from separate sources may not be comparable due to differences in sampling technique, location, and time. Despite these differences, general conclusions can be made. It is on the basis of these general conclusions and my own study that I will assess the potential for safe recreational shellfish harvesting in the Brickyard area.

Bacteria

Typhoid, salmonellosis, and gastroenteritis are examples of bacterial diseases that may be transmitted from the water to humans by shellfish (Kelly, 1971). Pathogenic bacteria may contaminate shellfish-growing waters, and consequently shellfish, from inadequately treated sewage, urban runoff, wet weather sewage overflowings and bypassings, and boat waste discharges (Jones and Stokes, 1977). TABLES 5-8 summarize bacterial surveys on water quality performed between Emeryville and the Berkeley Marina (refer to FIGURE 1 for sampling sites).

Date	End of Berk. Pier TC/FC[a]	Marina Entrance TC/FC	Aquatic Park TC/FC	E-1 TC/FC	E-2 TC	E-3 TC	E-4 TC
				Location (see FIGURE 1)			
1-19-73				11,000	2,400	2,400	4,600
2-8-73				430	290	2,400	930
3-5-73				430	230	2,400	4,600
4-5-73				930	930	930	>11,000
5-11-73				40[b]	90	90	≥24,000
6-13-73				1,500	4,600	2,100	4,600
7-11-73				2,400	11,000	2,400	≥ 2,400
8-6-73				90	930	4,600	≥24,000
9-12-73	75/9						
9-13-73	15/7	43/43					
9-14-73	93/9	43/23					
9-17-73	23/4	14/3					
9-21-73			>2,400/23				
9-24-73			240/9				

[a]TC = total coliform/100 ml
FC = fecal coliform/100 ml

[b]Underlined figures meet standards

TABLE 5. 1973 Coliform Bacteria Data.
Source: Sharpe, 1977.

Generally, the bacterial levels in the waters sampled exceed the standards set for shellfish-growing waters. Of all the water samples tested, only 22 met the standards (TC median MPN 70/100 ml and FC median MPN 14/100 m.). Of these 22, 18 were taken from the Berkeley Marina and Aquatic Park area. Low coliform levels in the Berkeley Marina could be due to the sewage pump-out facilities available there (Jones and Stokes, 1977). The high coliform levels on the shoreline appear to remain high throughout the year, although usually the worst bacterial conditions are expected during the rainy season when there is a great amount of urban runoff. This generality does not apply to the water quality results given in TABLES 5-8. The possibility of having seasonal harvesting even during the dry periods does not seem likely unless the bacterial levels can be drastically reduced.

The fecal coliform standard in shellfish meat is used as a supplement to growing water standards. And since high coliform levels were found in the shellfish growing waters, this would lead one to expect that the shellfish meat also contains high coliform levels. This could probably be the reason why I did not find any bacteriological tests performed on shellfish meat from beds #25 and #26. I did find bacteriological results on shellfish meat from a test made in 1972 at a site near Albany Hill (Sharpe, 1977). None of these samples met the

	April 7-8, 1972	April 17-18, 1972	April 22-23, 1972
Albany Hill	13,000 MPN/100g	1,700 MPN/100g	7,000 MPN/100g

fecal coliform MPN standard of ≤230/100 grams of shellfish meat.

Due to the lack of current data on bacterial levels in shellfish meat, I tested some samples from the Brickyard area. See the Appendix for complete details on methods and techniques used in sampling. Below are the results from the bacteriological tests I performed on mussels of the Brickyard.

Brickyard	March 4, 1982	
	Total Coliform (MPN) 24,000/100 grams	Fecal Coliform (MPN) 3,113/100 grams

Date	A-1 TC/FC[a]	A-3 TC/FC	B-1 TC/FC	B-3 TC/FC	C-1 TC/FC	C-3 TC/FC	E-1 TC	E-2 TC	E-3 TC	E-4 TC
1-19-74							750	2400	4600	930
2-1-74							11000	1100	4600	24000
3-13-74	62/13[b]	23/<4.5	130/23	23/<4.5	130/23	23/<4.5				
3-14-74							1500	1500	2400	1500
3-15-74	2300/62	620/6	130/23	2300/<4.5	230/6	62/62				
4-9-74							≥24000	≥24000	≥24000	≥24000
5-23-74							230	430	2400	<30
6-14-74							930	430	390	4600
7-9-74							≥24000	≥24000	≥24000	≥24000
8-16-74							2400	11000	440	≥24000
9-23-74							1500	4600	≥24000	≥24000
10-25-74							930	930	430	430
11-22-74							4600	430	230	2400
12-13-74							460	460	1500	1500

[a]TC = total coliform/100 ml
FC = fecal coliform/100 ml

[b]underlined figures meet standards

TABLE 6. 1974 Coliform Bacteria Data.
Source: Sharpe, 1977.

Date[b]	E TC[a]	F TC	G TC	Middle of Berk. Marina TC/FC	So. Edge Berk. Marina TC/FC	Berk. Marina near Bth H-5 TC/FC	Berk. Marina near Bth H-6 TC/FC	Berk. Marina near Bth I-6 TC/FC
1-16-76	110,000	240,000	2,300					
2-2-76	24,000	240,000	910					
3-1-76	24,000	240,000	15,000					
3-23-76	46,000	240,000	360					
4-13-76	24,000	240,000	910					
5-3-76	46,000	240,000	300					
5-17-76	24,000	240,000	7,500					
6-7-76	15,000	46,000	360					
6-23-76	24,000	240,000	360					
7-1-76	110,000	240,000	910	230/23	23/6[c]	4.5/4.5	62/62	4.5/4.5
8-?-76	110,000	46,000	910					
9-1-76	240,000	240,000	360					
9-29-76	240,000	110,000	24,000					
10-13-76	2,400	240,000	24,000					
11-12-76	110,000	240,000	24,000					
12-2-76	240,000	240,000	9,300					

Date	E TC/FC	F TC/FC	G TC/FC	Berk. Marina Entrance TC/FC	Berk. Seawall TC/FC	Marina Emeryville TC/FC
1-12-77	43,000/43,000	24,000/240,000	43,000/300			
2-8-77	93,000/21,000		2,400,000/290,000			
2-28-77				4/3	9/3	30/30
3-1-77				3/3	43/4	40/40

[a]TC = total coliform. FC = fecal coliform.

[b]1976 and 1977 data for sites E, F, G from Sharpe, 1977.
Data for other sites from Jones and Stokes, 1977.

[c]Underlined figures meet standards.

TABLE 7. 1976 and 1977 Coliform Bacteria Data.

The MPN grossly exceeded the standards. This result serves to confirm the poor quality of the mussels, as well as that of the overlying waters.

Viruses

Human enteric viruses are excreted in the fecal matter of infected persons. The release of viruses into the marine environment via sewage outfalls and polluted waterways presents a threat to shellfish harvesting. Shellfish from polluted waters may transmit serious viral illnesses such as infectious hepatitis and meningitis (Jones and Stokes, 1977). It has been determined that coliform bacteria

Date	Potter Street Storm Drain TC/FC[a]	Shoreline 500 Yds. South of Gilman St. TC/FC
8-9-79	7,000/2,200	1,700/130
8-20-79	35,000/2,300	330/230
8-21-79	490/230	1,700/1,700
8-22-79	4,900/230	790/490
8-23-79	490/130	490/79
8-24-79	1,700/230	490/140
9-17-79	24,000/24,000	920/94
9-18-79	54,000/2,300	94/11
9-19-79	1,300/70	350/13
9-20-79	130,000/3,300	23/2[b]
9-21-79	140/40	540/49

[a]TC = total coliform. FC = fecal coliform.

[b]underlined figures meet standards.

TABLE 8. 1979 Coliform Bacteria Data.
Source: Jarvis, pers. comm., 1982.

are not useful for indicating whether or not shellfish are contaminated by human enteric viruses. Presently the only way to determine whether enteric viruses are contaminating shellfish is to measure them directly (Cooper and Johnson, 1981). Drs. Cooper and Johnson, from the U.C. Berkeley School of Public Health, concluded from their study of Tapes japonica in San Francisco Bay shellfish beds that the low levels of polio virus recovered suggest that these viruses may not pose a significant public health hazard. However, none of the beds they tested included those near the Brickyard. Also, a number of viruses, such as Hepatitis Type A and the Norwalk Agent, were not studied.

Paralytic Shellfish Poison

Paralytic shellfish poison (PSP) is produced by the marine dinoflagellate Gonyaulax catanella. PSP is an important concern for the following reasons (Jones and Stokes, 1977): (1) the poison is among the most potent known; (2) shellfish may be safe in an area for years and then suddenly become toxic; (3) the toxin is heat-stable and does not degrade during cooking; (4) shellfish themselves do not appear harmed by consuming Gonyaulax; and (5) there is no field method for distinguishing between poisonous and non-poisonous shellfish. Blooms of Gonyaulax have a likelihood of appearing between May and October. Therefore, the California Department of Health issues an annual mussel quarantine from May 1 through October 31. Of all the shellfish, mussels concentrate the toxin to the greatest degree. Clams may be harvested as long as they are eviscerated before being consumed (Sharpe, pers. comm., 1982). The quarantine level for PSP is 80 mg/100 gm of shellfish meat (NSSP Manual of Operation, 1965).

In July of 1980 California had the second largest reported PSP incident in state history. Shortly after the outbreak, mussels from the Berkeley Marina and shoreline were tested for the presence of toxins. Mussel samples from both localities proved negative for toxin. However, mussels from Sausalito contained 960 mg of toxin. This result verified the need to continue to include bays and estuarine water bodies in the annual mussel quarantine (Sharpe, 1981).

Trace Metals

As can be seen from the list of FDA action levels, mercury is the only trace metal for which a strict limit has been set. In addition to mercury, cadmium and lead are toxic to humans at relatively low concentrations. Cadmium exposure in humans comes mainly from food, and the intestinal absorption of it is low. Food with high cadmium concentrations should be avoided because cadmium has a marked tendency to accumulate in the body.

Human exposure to lead comes from many sources. Five to ten percent of lead ingested with food and drink is absorbed into the body. Concentrations of lead in food must be fairly high before lead poisoning can occur from this source (Girvin et al., 1975). TABLE 9 summarizes data on trace metal levels at sites near Albany Hill and Point Isabel. Trace metal studies on shellfish beds #25 and #26 could not be found.

Point Isabel shellfish samples had gross contamination levels of lead, zinc, and cadmium. The high lead and zinc levels found in this area were attributed to heaps of electrical battery cases that had been dumped near the shore (see paper by John C. Thomas). The trace metal concentrations in the Albany Hill shellfish were below the FDA alert levels. However, high lead levels in dry weight measurements of shellfish samples were found in clams and a mussel sample. Bottom mud samples had high levels of mercury and zinc. These trace elements in the sediments would be available for uptake by shellfish (Sharpe, 1977).

Aside from these two places, the San Francisco Bay Shellfish Program has reported that most of the shellfish beds studied have trace metal concentrations

Location	Species	Cd	Cr	Cu	Pb	Hg	Zn	Source
Albany Hill	---[a]	.21	3.64	6.60	18.70[b]	.06	24.53	1
	Tapes	.40	1.20	1.40	3.20	.08	23.40	2
	Mya	.27	1.20	4.81	2.20	.07	17.00	3
	Mytilus	.47	1.20	1.50	2.96	.04	24.80	3
Point Isabel	Tapes	.30	.30	.90	7.30	.04	19.50	4
		.30	.20	.90	6.20	.04	18.70	4
		.39	.23	.80	135.00	.03	22.10	4
	Mya	.10	.20	2.80	8.50	.03	21.50	4
		.10	.30	2.80	9.60	.04	21.60	4
		.07	.20	3.10	47.00	.03	22.50	4
	Mytilus	.80	.20	1.20	64.00	.06	53.70	4
		.60	.30	.90	43.00	.06	37.50	4
		.80	.19	.90	81.00	.03	28.00	4

[a]Data not reported

[b]Underlined figures exceed alert limits

TABLE 9. Concentrations of Selected Trace Metals in PPM (mg/kg) Wet Weight.

Source:
1 - EPA, 1972
2 - Girvin et al., 1975
3 - Jones and Stokes, 1977
4 - McCleneghan, K., 1980

below existing or recommended FDA action levels (McCleneghan, 1980).

Synthetic Organic Compounds

Of the synthetic organic compounds, chlorinated hydrocarbons are one of the most important due to their wide use, great stability in the environment, and toxicity to certain forms of wildlife. If absorbed into the human body, they tend to be accumulated in fatty tissues rather than metabolized (Jones and Stokes, 1977). TABLE 10 summarizes levels of synthetic organic compounds in shellfish at Albany Hill and Point Isabel. I could not find data for the Brickyard shellfish.

Point Isabel shows a greater number of different pesticides and in higher concentrations than those found in Albany Hill. However, all of these levels are below existing or recommended FDA Action levels. The San Francisco Bay Shellfish Program has also consistently reported that most shellfish beds they have studied are well within the standards (McCleneghan, 1980).

Location	Species	Arochlor	Dieldrin	op'DDE	ppDDE	opDDD	opDDD	ppDDD	pp'DDT	PCB 1254	Trans-chlordane	Cis-chlordane	Trans-nonachlor	Oxy-chlordane	Source
Albany Hill	---[a]	88.0	4.0	7.2	2.0	1.2	1.6	2.8	3.6						1
	Tapes	38.1			6.91			5.0	3.46						2
	Mya	39.2			6.02			4.84	2.22						2
	Mytilus	138.0			16.4			10.6	7.27						2
Point Isabel	*Tapes*		5		5			5	5	50	5	5	5	5	3
					5	5		10	5	100	5	5	5		3
					5	5		8	5	50	5	5	5		4
	Mya		5		5			5	5	50	5	5	5	5	3
					9	5		10	5	85	5	5	5		3
					14	5		13	5	170	5	5	5		4
	Mytilus		7		36			62	5	380	20	20	14	5	3
					44	13		69	7	660	23	36	31		4
					36	12		47	5	630	15	23	15		4

[a]Data not reported

TABLE 10. Summary of Synthetic Organic Compounds in PPB Fresh Weight.

Source:
1 - EPA, 1972
2 - Girvin *et al.*, 1975
3 - McCleneghan, K., 1980
4 - Calif. Dept. of Fish & Game, 1982

Discussion

The potential for shellfish harvesting in the Brickyard with respect to shellfish resources, contaminant levels in shellfish, and public health standards, is severely hampered by the high levels of bacterial contamination in the overlying waters, as well as in the shellfish meat. The reported coliform levels generally exceeded the public health standards of 230 coliform/100 ml throughout the year. Even during the summer, when the lowest bacterial levels are expected due to minimum rainfall runoff, the shoreline water around the Brickyard showed up to 240,000 coliforms/100 ml. Apparently, the University Avenue storm drain and Strawberry Creek, which also flows into the same storm drain, discharge waters heavily contaminated with coliform bacteria all year round. A program to clean up the creek as well as one that would control surface runoff is needed if bacterial levels are ever to meet public health standards at this location.

One way to enhance the possibility of shellfish harvesting in light of high bacterial levels would be to establish depuration plants. Depuration refers to the practice of placing contaminated shellfish in a controlled environment where rapid elimination of contaminants takes place (Jones and Stokes, 1977). Shellfish can quickly eliminate bacterial contaminants with a residence time in depuration tanks of 48-72 hours. If there were a depuration plant in the Bay Area, it could offer the sports clammer depurated clams in return for undepurated ones at a nominal charge (Jones and Stokes, 1977).

As for the other substances examined in this study, they generally do not seem to pose any serious problems. For instance, the shellfish resources are sufficient to be considered for recreational use. And the levels of viruses, PSP, trace metals, and synthetic organic compounds in shellfish beds near the Brickyard, and those studied by the San Francisco Bay Shellfish Program, have generally met the standards or recommended alert levels, with the exception of Point Isabel and Albany Hill, which showed gross contaminations by metals and high levels of pesticides. It is important to note that few data are available on the levels of these contaminants found in shellfish specifically at the Brickyard. This is in part due to the fact that there is no agency responsible for monitoring the levels of these contaminants in shellfish in the San Francisco Bay. Therefore, the general findings of past studies may not necessarily apply to the shellfish along the Brickyard shores. Considering the complexity of water circulation within the bay, sources of pollution from places beyond the immediate study area, such as East Bay Municipal Utility District Waste Water Treatment Plant, Berkeley Dump, and industries along the waterfront, might affect the shellfish quality of the Brickyard area. This possibility needs to be studied.

Conclusion

In doing this research, I have found that a complete sanitary survey needs to be conducted in order to ascertain whether high levels of bacterial contamination are the only barrier to the safe consumption of shellfish. The survey should include an evaluation of all potential and actual sources of pollution to the Brickyard shore. If in fact high levels of bacteria contamination proves to be the only danger to human's consumption of shellfish in this area, then it would seem worthwhile to pursue the idea of establishing recreational harvesting with safeguards. Many people would stand to benefit from this, especially those who presently shellfish in order to supplement their diets. And as proteinaceous foods are becoming more expensive, it is possible that many more people will be attracted to shellfishing.

APPENDIX

Examination of Shellfish for Total Coliforma and Fecal Coliforms

Total and fecal coliform bacteria levels in shellfish samples were determined as per Recommended Procedures for the Examination of Sea Water and Shellfish (APHA, 1970). Processing was initiated within 24 hours of sample collection.

Sample collection data:

Date: 3-4-82

Time: 11:00 a.m. - 2:00 p.m.

Location: See FIGURE 1. "X" marks the collection sites.

Samples collected consisted of 27 legal-sized Bay Mussels (1½" or larger) and 5 Japanese littleneck clams. As not enough clams were found to obtain a representative sample, the experiment was based solely on mussels.

At 2:00 p.m. mussels were refrigerated until 11:00 a.m. of the next day, a total of 21 hours.

Laboratory data

Weight of mussel meat and liquor = 331 g.

By mistake 331 ml of stock buffered water was added instead of 331 ml of buffered dilution water.

Presumptive test results after 79 hours of incubation:

5 positive tubes for 1 g, 0.1 g, and 0.01 g dilutions. All dilution tubes with 0.001 g were negative. Most Probable Number for 5, 5, 0, positive test tubes = 24,000/100 g.

(continued)

APPENDIX

(continued)

Inoculated BGB and EC broth with cultures from the 0.01 dilution tubes, planting 3 portions for each tube (3-9-82 at 3:00 p.m.).

Confirmative test results (3-10-82 at 2:00 p.m.)

4 positive tubes and 11 negative tubes of EC broth

$$MPN = \frac{100 \times P}{N \times T}$$

P = # of positive tubes
N = # of negative tubes
T - Total volume tested

$$\text{MPN of fecal coliform} = \frac{100 \times 4}{.11 \times .15} = 3113/100 \text{ g of mussel meat}$$

(3-11-82 at 2:00 p.m.). All 15 tubes of BGB were positive, therefore MPN of total coliform is confirmed to = 24,000/100 g of mussel meat.

REFERENCES CITED

American Public Health Association (APHA), 1970. Recommended procedures for the examination of sea water and shellfish, 4th ed.: American Public Health Association, New York, 105 pp.

Bradford, W. and S.N. Luoma, 1979. Some perspectives on heavy-metal concentrations in shellfish and sediment in San Francisco Bay, California: U.S. Geological Survey, unpublished data, 69 pp.

California Department of Fish and Game, 1982. Investigations of selected environmental contaminants in San Francisco Bay shellfish: A report to San Francisco Bay Shellfish Program, S.F. Bay Regional Water Quality Control Board. Laboratory report No. 82-1, 36 pp.

California Department of Health Services (DOHS), n.d., Breuer, Robin: unpublished data.

California Regional Water Quality Control Board (RWQCB), S.F. Bay Region, 1978. Internal Memo: Staff report on the Regional Board Program to open shellfish beds for recreational use, from F. Jarvis to F. Dierker, March 2, 1978. File No. 1460.00.

__________, 1978. Resolution No. 78-8 (Policy Statement with respect to the Regional Board Program to open S.F. Bay shellfish beds for direct recreational use), Attachment #1, 10 pp.

__________, 1980. Information sheet on the S.F. Bay Shellfish Program, (March), 1 p.

__________, 1980. Annual Progress Report, October: Prepared by F. Jarvis, 3 pp.

__________, 1981. S.F. Bay Shellfish Program Preliminary sanitary survey report for the East Bay study area: 263 pp.

__________, 1982. Annual Progress Report, January: Prepared by F. Jarvis, 3 pp.

REFERENCES CITED

(continued)

Cooper, R.C., D. Jenkins, L. Young, 1976. Aquatic microbiology laboratory manual: Prepared by Association of Environmental Engineering Professors under EPA grant No. T-900457001-4, III-E-2-6p.

Cooper, R.C., K.M. Johnson, D.C. Straube, and D. Koyama, 1981. Detection of human enteric viruses and coliform bacteria in S.F. Bay waters and shellfish: Sanitary Engineering and Environmental Health Research Laboratory, College of Engineering and School of Public Health, U.S. Berkeley, SEEHRL Report No. 81-1, 76 pp.

Girvin, D.C., A.T. Hodgson, and M.H. Pantetz, 1975. Assessment of trace metal and chlorinated hydrocarbon contamination in selected San Francisco Bay estuary shellfish: Lawrence Berkeley Lab, University of California, UCID-3778, 82 pp.

Jarvis, F., San Francisco Bay Shellfish Project Manager, RWQCB. Personal communication, April, 1982.

Jones & Stokes Assoc., 1977. An assessment of the potential for commercial and recreational harvesting of S.F. Bay shellfish: Prepared for Association of Bay Area Governments, Claremont Hotel, Berkeley, CA, 171 pp.

Kelly, C.B., 1971. The health hazards associated with the consumption of shellfish from polluted waters: Environmental Protection Agency Division of Water Hygiene, 21 pp.

McAllister, F.D., and T.O. Moore, Jr., 1982. Selected shellfish resources of San Francisco Bay: their distribution, abundance, use, public access and recommended management alternatives: California Department of Fish and Game. A report to to San Francisco Bay Shellfish Program, 168 pp.

McCleneghan, K., 1980. San Francisco Bay shellfish study, February 1980: Trace metal and synthetic organic compound concentrations in selected bivalve mollusks: California Department of Fish and Game; Fish and Wildlife Water Pollution Control Laboratory, Lab. memorandum Report No. 80-2, 23 pp.

Sharpe, C.A., 1977. An analysis of the factors affecting the possible establishment of a commercial shellfish operation in San Francisco Bay along the Berkeley shoreline: State Department of Health Sanitary Engineering Section, 52 pp.

__________, 1980. Paralytic shellfish poison: California Department of Health Services, Sanitary Engineering Section, 75 pp.

__________, Senior Sanitary Engineer, State Health Department. Personal communication, May 1982.

Sutton, J.E., 1981. Shellfish resources of eastern S.F. Bay: Distribution, abundance, public access and use. Prepared for East Bay Municipal Utility District, Special District No. 1. Jefferson Associates, Inc., S.F., CA, 168 pp.

U.S. Environmental Protection Agency, 1972. Water quality sources of pollution and abatement needs for S.F. Bay, Calif.: Preliminary Draft: National Field Investigations Center, Denver, Colorado and Region IX, San Francisco, California, VIII, 11 pp.

__________, 1974. Shellfish study of San Francisco Bay, April-June, 1972, Technical Report-EPA-909/9-74-003: Surveillance and Analysis Division, 23 pp.

U.S. Department of Health, Education, and Welfare, 1965. National shellfish sanitation program manual of operations Part I: Sanitation of shellfish growing areas: Division of Environmental Engineering and Food Protection, Shellfish Sanitation Branch, Washington, D.C., 32 pp.

Vandre, V., 1980. Harvesting of clams, mussels, and oysters, a real possibility: Outdoor California, v. 41, no. 4, pp. 4-6.