

## 4.4 Public Health

### 4.4.1 Analyses of Texas Department of Health Bacteriological Data

For analysis, fecal coliform concentrations were utilized when available and log transformed to linearize the geometric process of bacterial population growth. Total coliform concentrations were included in the database, but not used. Sample sites were geographically categorized into GBEP segments. These segments were then combined, for analysis, into major bays and tributaries: the Houston Ship Channel, Trinity Bay, Upper and Lower Galveston Bay, East Bay, West Bay, and Christmas Bay.

Bacteriological data were collected at various sample sites from 1963 to 2003, but fecal coliform analyses were not started until 1968. Most of the samples collected in the 1960s were analyzed for total coliform concentration, not fecal coliforms. Samples collected in 2003 were not used because they represent a partial year. Sample years were combined into decades: 1968-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2002. Months were categorized into seasons: December/January/February = Winter, March/April/May = Spring, June/July/August = Summer, and September/October/ November = Fall. The analysis of fecal coliform data consisted of analyses of variance (ANOVA), comparison of means for major effects, and stepwise regression.

An ANOVA examined the effects of location, i.e. major bay or Houston Ship Channel, time period, i.e. decade, and season on the parameter fecal coliform. Sample sizes for the categories in each of the main effects are large. There are striking differences in the number of samples across decades and bay segments. Houston Ship Channel has fewer samples than major bays and the 1960s had fewer samples than other time periods.

Tests of these classifiers, location, time period, and season, detected significant effects from all of them on fecal coliform number. Bays/tributary showed a significant difference in coliform count ( $p < 0.001$ ). This effect is largely attributed to the high values in the Houston Ship Channel and the low values in East and Trinity Bays. Results of comparison among the five bays and Houston Ship Channel using the Tukey Honestly Significant Difference test are shown in Table 4.4.1.1. The effect of season is also significant with winter exhibiting the highest mean concentration. The effect of decade is not significant, but there is a highly significant interaction among decade, season and bay.

Table 4.4.1.1. General linear model test of the effects of bay or tributary, decade, and season on log transformed fecal coliform concentrations.

A. Sample Sizes for Main Effects

<b>Classifier</b>		<b>N</b>
<b>BAY</b>	East	4,435
	Christmas	1,887
	Galveston	15,224
	Houston Ship Channel	482
	Trinity	3,368
	West	3,878
<b>SEASON</b>	Fall	6,808
	Spring	8,359
	Summer	5,086
	Winter	9,021
<b>DECADE</b>	1968-1969	141
	1970-1979	2,273
	1980-1989	6,704
	1990-1999	14,942
	2000-2003	5,214

B. Analysis of variance results with mean squares and F values for all main effects and interaction terms in the model.

<b>Source</b>	<b>Type III Sum of Squares</b>	<b>df</b>	<b>Mean Square</b>	<b>F</b>	<b>Significance</b>
Corrected Model	1,649.798	104	15.863	41.279	<0.001
Intercept	374.064	1	374.064	973.378	<0.001
BAY	68.121	5	13.624	35.452	<0.001
DECADE	31.285	4	7.821	20.352	<0.001
SEASON	12.047	3	4.016	10.449	<0.001
BAY * DECADE	58.015	20	3.223	8.387	<0.001
BAY * SEASON	24.069	15	1.605	4.175	<0.001
DECADE * SEASON	37.327	12	3.111	8.094	<0.001
BAY * DECADE * SEASON	97.310	47	2.070	5.388	<0.001
Error	11,091.521	28,862	0.384	-	-
Total	30,093.367	28,967	-	-	-
Corrected Total	1,2741.319	28,966	-	-	-

R Squared = 0.129 (Adjusted R Squared = 0.126)

Table 4.4.1.2 Mean log (fecal coliform) concentrations in major bays and the upper Houston Ship Channel. Sample number (N) is shown. Subset refers to the designation of homogeneous groups by the Tukey test between means. Designation by the same letter is used to denote no significant difference between means.

<b>Bay or Tributary</b>	<b>N</b>	<b>Mean</b>	<b>Subset</b>
<b>East</b>	4,435	0.578	a
<b>Trinity</b>	3,368	0.664	b
<b>West</b>	3,878	0.804	c
<b>Galveston</b>	15,224	0.822	c
<b>Christmas</b>	1,887	0.826	c
<b>Houston Ship Channel</b>	482	1.399	d

The results of the Tukey test comparing means between decades are shown in Table 4.4.1.3. There are two homogeneous groups. The difference is largely due to the 1960s having lower fecal coliform concentrations than the other decades. This effect should be placed in the context of fewer samples analyzed for fecal coliforms in the decade of the 1960s, consisting of only two years (1968-1969). The values showed a significant difference ( $p < .001$ ) to all other decades, except the 1980s, when compared in a Tukey Honestly Significant Difference test. The 1970s, 1990s and 2000s concentrations were significantly higher than the 1960s ( $p > 0.05$  in the Tukey test). When comparing interactions between independent variables, Bays/Tributaries and Decades showed a significant interaction ( $p < .001$ ), while Bays and Seasons showed no significant interaction ( $p = 0.247$ ). In this analysis,  $R^2$  was only 0.103, with an adjusted R squared of 0.100.

Table 4.4.1.3 Mean log fecal coliform concentrations of Galveston Bay samples collected in different decades. Sample number (N) is shown. Subset refers to the designation of homogeneous groups by the Tukey test between means. Designation by the same letter is used to denote no significant difference between means.

<b>Decade</b>	<b>N</b>	<b>Mean</b>	<b>Subset</b>
<b>1968-1969</b>	141	0.678	A
<b>1970-1979</b>	2,273	0.815	B
<b>1980-1989</b>	6,704	0.731	a, b
<b>1990-1999</b>	14,942	0.782	B
<b>2000-2003</b>	5,214	0.796	B

Seasons showed significant effect in the ANOVA and each season proved to be significantly different in the Tukey test as shown below (Table 4.4.1.4). Summer exhibited the lowest mean concentration and winter the highest.

Table 4.4.1.4. Mean log fecal coliform concentrations of Galveston Bay samples collected in different seasons. Sample number (N) is shown. Subset refers to the designation of homogeneous groups by the Tukey test between means. Designation by a different letter is used to denote significant difference between means.

Season	N	Mean	Subset
Spring	8,359	0.777	A
Summer	5,086	0.505	B
Fall	6,808	0.697	C
Winter	9,021	0.985	D

An ANOVA test conducted after omitting samples from the Houston Ship Channel showed very similar effects. All of the main effects and interaction terms were significant at  $p < 0.001$ . The homogeneous subsets determined by Tukey test also remained the same with the caveat that Houston Ship Channel was no longer a category in the classification of bays/location. Although the tests showed significant effects, Bays, decades, seasons and their interactions explain little of the variation in fecal coliform abundance in the TDH dataset. Adjusted  $R^2$  for the ANOVA was equal to only 0.111.

A stepwise regression analysis of environmental variables and log transformed fecal coliform concentration was performed. The variables provided were 24-hour total rainfall, 4-day total rainfall, and 7-day total rainfall, river stage, salinity, and wind speed. The dependent variable was log fecal coliform concentration. The dataset contained a sample number of 16,029 and the step criterion was set at  $R^2 > 0.01$ . There were four variables selected by the regression process: river stage, rain in the preceding seven days, water temperature and salinity. Step 1 had a  $R^2 = 0.136$  (representing the proportion of variance in fecal coliform concentration that can be explained by river stage data), Step 2 had a  $R^2 = 0.204$  (representing the explanatory power of river stage plus total rainfall in the seven days preceding the sample). Step 3 had a  $R^2$  of 0.277 (representing the fecal coliform variance explained by river stage, 7-day rainfall, and water temperature). Step 4 had a  $R^2$  of 0.306 (representing the covariance of river stage, 7-day rainfall, water temperature and salinity with fecal coliform concentrations). For the four regression steps meeting the criterion, the significance value ( $p$ ) was less than 0.001. The regression equation generated is  $\text{Log Fecal Coliform} = 0.012(\text{river stage}) + 0.085(7 \text{ day rainfall}) - 0.016(\text{water temperature}) - 0.022(\text{salinity}) + 1.823$ . This equation predicts a relationship that explains more than 30% of the variation in fecal coliform concentrations reported in the dataset.

The classification factors examined by ANOVA: major bay or tributary, time period/decade, and season are less able to explain the variation in fecal coliform numbers than the variables included in the stepwise regression. The adjusted  $R^2$  for the ANOVA, which includes main effects and interaction effects, is only 0.126. The regression equation derived from the first four steps using the continuous variables river stage, rainfall in the preceding seven days, water temperature and salinity has an  $R^2$  of 0.306. Fecal coliform concentrations have been more influenced by episodic events related to weather than by fixed factors, such as development patterns around a major bay or a decades long trend in water quality.

#### 4.4.2. Seafood Safety in Galveston Bay: A Data Comparison

The Texas Department of Health (TDH) conducted a series of health consultations involving extensive surveys of contaminants in fish and crabs from the major segments of the Galveston Bay system from 1998 to 2000. The Texas Parks and Wildlife Department (TPWD) coordinated the National Coastal Assessment (NCA) monitoring program in the summers of 2000 and 2001 that included analyzing contaminants in tissue from fish and shrimp. The two studies differ in their objectives and have experimental designs that are not comparable. However, each study is relevant in its own way to the issue of contaminant levels in organisms of Galveston Bay. The data cannot be disregarded, but must be analyzed in the proper context.

The TDH study used large fish and crabs collected from locations selected to maximize detection of contaminants. The NCA study used small fish and shrimp collected from sample sites chosen to optimize coverage of the bay system. The TDH used fish muscle tissue while the NCA analyzed a composite of fish tissues. Both used composite tissue samples for crustaceans. The Status and Trends project performed no statistical tests that directly compared the values from the two studies due to the differences in sampling methodologies. Pesticides and metals were chosen to illustrate the similarities and differences between the two studies.

Table 4.4.2.1 shows the results for selected pesticides separated by study and sample type, i.e. fish or crustacean. In both studies, detectable concentrations of pesticides are found more often in fish than in crustaceans. Fish show detectable levels of ten pesticides in the NCA study and eight pesticides in the TDH study, while crustaceans show detectable levels of only four pesticides in both studies. When a study finds a pesticide in both fish and crustaceans, the level tends to be higher in fish. The exceptions are DDT in the TDH study and toxaphene in the NCA study.

There are some rather large differences between the two studies in the concentration of pesticides detected in the same type of organism. DDT, dieldrin, endrin and toxaphene show large concentration differences between the two studies with the NCA study providing the highest concentrations. This demonstrates that exposure to contaminated Galveston Bay water and sediment can produce detectable levels of contamination even in young, small fish or crustaceans. It also shows the uneven distribution of contaminants in whole body versus edible tissue. Certain compounds, e.g. organics, are usually much higher in whole fish than in edible tissue. Mercury is higher in muscle tissue than in whole body measurements. Many of the differences between the two studies result from differences in methodology. However, both studies show that toxic compounds are bioavailable to fish and shellfish in Galveston Bay (Kirk Wiles, personal communication, 2003).

Table 4.4.2.1. Concentrations of eleven pesticides in fish and crustacean samples analyzed in the National Coastal Assessment (NCA) program collected in 2000 and in the Texas Department of Health (TDH) study collected in 1999 and 2000 from the Galveston Bay system. Results of comparisons of mean concentrations in fish and crustacean within study are shown.

Pesticide	Tissue Concentration (ug/kg)				Difference (Fish – Crustacean Vales)	
	NCA 2000 Study		TDH 1999-2000 Study		NCA	TDH
	Fish (n=43)	Shrimp (n=5)	Fish (n=192)	Crab (n=53)		
4,4'-DDD	9.51	0	1.27	0.24	*	ns
4,4'-DDE	7.91	6.74	3.40	1.19	ns	*
4,4'- DDT	6.71	2.88	0.13	0.44	ns	ns
Dieldrin	3.46	0.00	0.23	0.00	ns	*
Endrin	4.94	0.00	0.00	0.00	ns	--
Heptachlor	0.00	0.00	0.02	0.00	--	ns
Hexachlorobenzene	2.08	0.00	0.28	0.00	ns	*
Chlordane	7.03	5.19	13.90	9.30	ns	ns
Lindane	1.43	0.00	0.03	0.00	ns	ns
Mirex	0.25	0.00	0.00	0.00	ns	--
Toxaphene	304.76	447.39	0.00	0.00	ns	--

\* = p<0.05

ns = not significant

-- = not sampled

Metals are commonly sampled in surface water and sediment monitoring programs(see Sections 4.1 and 4.2). The NCA study extends this type of monitoring to tissue contamination and analyzes concentrations of 13 metals in tissue. The TDH study analyzes only seven metals because the purpose is to assess risk to human consumers and the likelihood of tissue concentrations of some metals being high enough to cause physiological damage is extremely low.

The concentrations of those metals sampled in both studies are similar. Over half of the metals sampled in both studies show significant differences between fish and crustacean tissue. In some cases, this is clearly caused by a difference in physiology, e.g. higher copper in crustaceans that use the metal in their blood pigment. The difference in cadmium concentration may be due to the difference in habitat. Lead and zinc show reversed patterns in the two studies. In the NCA study, lead and zinc are higher in fish. In the TDH study, lead and zinc are higher in crabs.

Table 4.4.2.2. Concentrations of 13 metals in fish and crustacean samples analyzed in the NCA program collected in 2000-2001 and six metals analyzed in the TDH study from 1999 to 2000. Results of comparisons of mean concentrations in fish and crustacean sampled in the two studies are shown.

Metals	Tissue Concentration (ug/kg)				Difference (Fish – Crustacean Vales)	
	NCA 2000-2001 Study		TDH 1999-2000 Study		NCA	TDH
	<u>Fish</u> Mean (n=89)	<u>Shrimp</u> Mean (n=9)	<u>Fish</u> Mean (n=246)	<u>Crab</u> Mean (n=71)		
Silver	0.0024	0.0603	--	--	ns	--
Aluminum	61.487	35.322	--	--	ns	--
Arsenic	0.504	0.481	0	0	ns	--
Cadmium	0.013	0.070	0.005	0.083	*	*
Chromium	1.681	0.532	--	--	*	-
Copper	0.880	11.068	0.103	8.127	*	*
Iron	72.647	10.198	--	--	*	--
Mercury	0.042	0.026	0.049	0.017	ns	ns
Nickel	0.511	0.179	--	--	*	--
Lead	0.126	0.058	0.009	0.020	*	*
Selenium	0.686	0.721	0.585	0.698	ns	ns
Tin	0.089	0.056	--	--	ns	--
Zinc	37.201	15.956	3.625	37.213	*	*

\* = p<0.05

ns = not significant

-- = not sampled

The NCA analysis of metals occurred in both 2000 and 2001. Sample sites varied between years, as did species of fish sampled. The concentrations of six metals are significantly different between years. Arsenic, cadmium, nickel and selenium are significantly higher in 2000. Aluminum and tin are significantly higher in 2001. These results demonstrate the variation across space and/or fluctuation over time of many contaminants entering the bay system.

The examination of results from the TDH and NCA studies in the context of this Status and Trends analysis emphasizes problems associated with combining datasets obtained from many sources and collected for a variety of purposes. There are similarities that provide some validation for the merging of different datasets, but there are also striking differences that cause one to question the relevance of conclusions drawn from short-term, localized or small sample size studies to the entire Galveston Bay system. The impact of different sampling strategies on the monitoring data collected needs to be examined in more detail.