Comparing Water Quality between Shellfish Management Areas in Tillamook Bay, Oregon

K.M. Busse[1] and Ralph J. Garono[1,2], Ph.D.

[1] College of Oceanic and Atmospheric Sciences
Oregon State University
Ocean Admn Bldg 104
Corvallis, Oregon 97330
(541) 737 - 2492 phone
(541) 737 - 2064 fax
kbusse@oce.orst.edu

[2] Earth Design Consultants Inc.
800 NW Starker, Suite 31
Corvallis, Oregon 97330
(541) 757- 7896 phone
(541) 757 - 7991 fax
rgarono@earthdesign.com

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Abstract

The Tillamook community is concerned about oyster bed closures, declines in salmonid populations, and decreases in recreational use of estuarine resources which have been linked to water quality degradation in Tillamook Bay. In this study, both spatial and temporal patterns in Tillamook Bay fecal coliform bacteria (FCB) concentrations were examined between designated shellfish management areas using Department of Environmental Quality STORET monitoring data. A one-way ANOVA was used to compare log transformed FCB concentrations in three types of management areas: prohibited, restricted, and conditional. We found (1) a statistically significant ($P < .05$) difference in Tillamook Bay water quality between all areas, (2) a statistically significant ($P < .05$) decrease in FCB concentrations from 1979–83 to 1984-88, and (3) a statistically significant ($P < .05$) increase in FCB from the 1984-88 to 1989-93. If the goal of designating shellfish management areas is to relate water quality to human health risks, then monitoring practices need to be re-evaluated in order to draw more refined conclusions about water quality trends in Tillamook Bay.

Introduction

Tillamook Bay was designated as an estuary of National significance and included in the US EPA National Estuary Program (NEP) in October, 1992. Designation of environmental priority problems is a key component of the NEP process. The Tillamook Bay National Estuary Project (TBNEP) has identified three priority problems: (1) water-borne pathogen contamination affecting the agricultural and commercial shellfish industries, (2) sedimentation affecting fresh and saltwater flows, and (3) habitat degradation affecting salmon spawning, stream temperatures, and other watershed functions (TBNEP 1994).

The Tillamook Bay estuary is located on the Northwestern coast of Oregon and is the third largest estuary in the state (Figure 1). Tillamook Bay is approximately 9.5 km long, 4.5 km wide at high tide, and relatively shallow with an average depth of 1.8 m (TBNEP 1996). The estuary is 35 km^2 with 50-60% of the bay existing as tidal flats (Pearson et al. 1996). The Tillamook Watershed is made up of five river basins which drain into the bay: Miami, Kilchis, Wilson, Trask, and Tillamook (Figure 2).

Natural resource use in the Tillamook Watershed includes agriculture (dairy), forestry, and fish and shellfish harvest practices. Land use varies within the watershed; primarily with dairy industries on privately owned land in the lower watershed and forest industries in publicly owned land of the upper watershed (Strittholt *et al.* 1997). Over 180 combined animal feeding operation (CAFO) permits have been issued in agricultural areas. Six oyster growers, two to three clam divers, and the public use the bay for shellfish harvesting (ODA 1995).

The ODA regulates the commercial harvest of shellfish in Tillamook Bay and is responsible for notifying the public of shellfish safety closures based on the Food and Drug Administration's National Shellfish Sanitation Program (TBNEP 1994). This program sets classification standards for shellfish harvest areas based on water quality samples taken during adverse pollution conditions (sewage spills) or heavy rainfall. The highest classification or an "approved" area must have a geometric mean of fewer than 14 FCB per 100 mL, with not more than 10% of the samples exceeding 43 organisms per

100 mL (DEQ 1994, TBNEP 1994). Most Tillamook Bay harvest areas are classified as "conditionally approved" which allows FCB geometric means to exceed 14 FCB/100 mL. When FCB counts exceed the standard, shellfish harvesting is restricted or banned in the bay (TBNEP 1994).

Ideally, the ODA Commercial Shellfish Harvest Plan is a management plan that opens and closes commercial harvest based on water quality. The management plan separates the bay into two prohibited, two conditionally approved, and one restricted management area (Figure 3) (TBNEP 1994). Since most shellfish harvest occurs in conditional areas (Figure 4), it is especially important to detect water quality trends and minimize the health risk of FCB contamination in these regions.

Prohibited regions are areas where no harvest is allowed while conditional and restricted areas ban harvest based on the Wilson River gauge and precipitation patterns (TBNEP 1994). Rather than using FCB water quality monitoring data, gauge and precipitation levels are currently used as standards for harvest because they provide more instantaneous results. When the Wilson River gauge rises to 7 feet, all conditionally approved areas are closed. When more than 1" of rainfall occurs within a 24-hour period, one of the conditional areas is closed while the other remains open provided the Wilson gauge is not above 7 feet and there is not a sewage or toxic spill (TBNEP 1994). However, there is no evidence to suggest that the Wilson River gauge is correlated with FCB concentrations in the bay. Although bacterial counts usually decrease in 48 hours, management areas remain closed to commercial harvesting for at least 5 days after the period of heavy precipitation (Laimons *et al.* 1976, TBNEP 1994). When harvest areas are re-opened, it is the responsibility of the ODA to notify agencies, commercial harvesters, and the local media.

Tillamook Bay water quality has been a concern of the Tillamook community since the estuary is one of Oregon's primary shellfish harvest areas covering approximately 1,000 acres or 10% of the bay (Musselman 1986). Based on water quality, oyster beds are closed an average of 50-60 days each year by the Oregon Department of Agriculture (TBNEP 1994, ODA 1995). The concentration of water-borne pathogens in shellfish tissue is a problem because the shellfish are eaten either raw or cooked which is not likely to destroy all pathogens (Dorsey-Kramer 1996, TBNEP 1994). Therefore, it is important to study spatial and temporal differences of fecal coliform bacteria since contaminated shellfish are a health risk to the community.

This study examined patterns in FCB concentrations in Tillamook Bay. Fecal coliform concentrations have been used as an indicator of water quality because the origin and transport of these bacteria and of water-borne pathogens are directly related to land use practices (Dorsey-Kramer 1996). Point source pollution of FCB includes sewage treatment plants while non-point sources include manure fertilizers, failing septic systems, and animal waste runoff (Musselman 1986, Strittholt *et al.* 1997). Environmental conditions such as precipitation and bay circulation also influence patterns of FCB concentrations in the Tillamook Bay.

Study Objectives

1. Do fecal coliform bacteriaconcentrations differ between ODA prohibited, restricted, and conditional shellfish management areas?

2. How do fecal coliform bacteria concentrations change in each management area between 1979-83, 1984-88, and 1989-93?

Methods

We examined 15 years of Department of Environmental Quality (DEQ) STORET data (1979-1993) from 14 sampling stations in the bay with a total of 1835 observations for all regions. Typically, DEQ fecal coliform bacteria sampling was unreplicated for individual sites. Therefore, we assigned each sample station to one of three ODA management area types: prohibited, restricted, and conditional (Figure 3). Each of these regions were assumed to be well-mixed (homogenous) and adequately represented by existing STORET sampling stations.

To examine spatial patterns in water quality, we used the 15 years of data to determine an overall trend of FCB concentrations between prohibited, restricted, and conditional management areas. All statistical analysis were done using SPSS version 7.5. First, the distribution of FCB concentrations (CFU/100 ml) was tested with the Levene Test. Since bacterial concentrations were not normally distributed, the data required a log transformation before doing a one way ANOVA (Marija 1993). A one way ANOVA was then used to determine differences in the log transformed mean of FCB concentrations between the prohibited, restricted, and conditional management areas (significance was at $P < .05$). A Tukey multiple comparison test *a posteriori* was used to determine how regions differed from one another (Zar 1984).

We then broke the 15 years of FCB data into three distinct five year periods (1979-83, 1984-88, and 1989-93) to examine temporal trends in water quality for *each* management area. A one way ANOVA was used to determine differences in the log transformed mean of FCB concentrations between the three time periods. The Tukey multiple comparison test was used to determine how time periods differed from one another (Zar 1984).

Results

Comparisons were made between 15 years of FCB data grouped by prohibited, restricted, and conditional regions. We found no statistical difference ($P = 0.507$) in concentrations between the prohibited and restricted regions (Figure 5: indicated by A). However, FCB levels were significantly lower ($P << 0.001$) in the conditional management area (Figure 5: indicated by A/B).

The 15 years of FCB data were then broken into three, five year periods: 1979-83, 1984-88, and 1989-93. We found an overall decrease in FCB concentrations from 1979-83 to 1984-88. However, FCB concentrations increased from the 1984-88 to 1989-93. Prohibited and conditional results show that all three time periods were significantly different ($P < .05$) from one another (Table 1) (Figure 6: indicated by A/B/C). Note that each of these graphs now represents a different management area with the x axis labeled as time. In the restricted region, FCB concentrations from 1979-83 and 1989-93 were not significantly different from one another while they were significantly different from concentrations in the period 1984-88 (Table 1) (Figure 6: indicated by A/B). Finally, the conditional region had the lowest count of FCB through all three time periods.

Time Period		Management Prohibited	Area Restricted	p values Conditional
1979-83	1984-88	*	*	*
	1989-93	*	NS	*
1984-88	1979-83	*	*	*
	1989-93	*	*	*
1989-93	1979-83	*	NS	*
	1984-88	*	*	*

Table 1. Multiple comparison statistical p value results for P = prohibited, R = restricted, and C = conditional shellfish management areas.
NS = no significant difference between time periods
** = $P < 0.05$ or significant difference between time periods*

Conclusions

This study examined both spatial and temporal patterns in FCB concentrations in Tillamook Bay. We found that differences in water quality existed between prohibited, restricted, and conditional areas: the conditional management area had significantly lower concentrations of FCB than the prohibited and restricted regions. Results also showed an overall reduction in FCB concentrations between 1979 -83 and 1984-88. Results from a similar water quality study for tributaries in the Tillamook watershed also documented a significant decrease in FCB concentrations after 1985 (Dorsey-Kramer 1996). Researchers attributed tributary water quality improvements to the installation of manure handling facilities and other Best Management Practices (BMP) implemented in 1982 (Wiltsey 1990, Dorsey-Kramer 1996). BMPs such as improving fencing and off-site watering sources were designed to reduce the number of cattle from entering streams and thus thought to reduce FCB inputs.

However, temporal results of this study showed that fecal coliform bacteria concentrations began to increase between 1984-88 and 1989-93. Possible causes for FCB concentrations may include doubling cattle numbers since 1980, changing precipitation patterns, shifting dairy farm ownership, decreasing BMP implementation or maintenance, or decreasing riparian vegetation which act to filter pollutants. Thus, health risks related to FCB can be affected by changes in land use and population patterns. Further studies are needed to more closely examine causes for decreased Tillamook Bay water quality.

Recommendations

If shellfish management areas are established to address human health risks related to water quality in Tillamook Bay, then the designation of these management areas should be re-evaluated to reflect water quality standards. Further monitoring and experimental studies should be conducted to improve assessments of Tillamook Bay water quality. Several management recommendations can be made based on this study's results.

- Water quality sampling should be conducted on a regular basis.
- Samples should be taken more frequently to examine relationships between precipitation and FCB concentrations since monthly sampling records trends but does not adequately address the impact of episodic rainfall events.
- The distribution of sample sites should be re-evaluated and include more sites in the restricted region to decrease variability in data.
- Management area recommendations should be re-evaluated for the restricted area which is not significantly different from prohibited areas.
- If management recommendations are to be based on water quality, they should have greater links to land use practices in the upper and lower watersheds (*i.e.*, riparian buffer design and maintenance).

- Management plans and data collection points could be based on an existing bay circulation model rather than using gauge and precipitation patterns (TBNEP 1994).
- Studies should be designed to monitor the effectiveness of BMP implementation and to determine the possible effects of altering shellfish management area designations.

The goal of all National Estuary Projects is to develop a science-based Comprehensive Conservation Management Plan. The process of coordinating a CCMP requires the production of Scientific-Technical Characterization Reports from existing data (Strittholt *et al*. 1997). Results from this study of existing water quality data can be used to develop more robust shellfish management strategies for the Tillamook Bay CCMP.

In conclusion, continued monthly monitoring of the bay is necessary to further assess long-term trends in water quality. However, this study suggests that the pattern and frequency of sampling should be re-evaluated to provide more data for making reliable shellfish management decisions. As more data become available, Tillamook Bay water quality should continually be re-assessed.

Acknowledgments

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REFERENCES

DEQ. 1994. *Oregon Administrative Rules (OAR).* Chapter 340, Division 41. Oregon Department of Environmental Quality. Portland, Oregon. May 1994.

Dorsey-Kramer. 1996. *A statistical evaluation of the water quality impacts of best management practices installed at Tillamook county dairies.* Bioresource Engineering Dept. Oregon State University, M.S. Thesis, 208 pp.

Laimons, O. and D. Demory. 1976. *Classification and utilization of oyster land in Oregon.* Oregon Department of Fish and Wildlife, Portland, OR.

Marija J. Norusis. 1993. *SPSS for windows: base system user's guide release 6.0.* Chicago: SPSS Inc.

Musselman, J.F. 1986. *Sanitary survey of shellfish waters, Tillamook Bay, Oregon.* Department of Health and Human Services, Public Health Service, Food and Drug Administration, Shellfish Sanitation Branch, Portland, Oregon.

ODA. 1995. *ODA Shellfish growing area triennial evaluation.* Oregon Department of Agriculture, Portland, Oregon. August 1995.

Pearson, Phillip, Antonio M. Baptista, and Mauro Alves. 1996. Technical Report CCALMER TR 96/1: prepared for the Tillamook Bay National Estuary Project.

Strittholt, James R., Ralph J. Garono and Pamela A Frost. 1997. *Spatial Patterns in Land Use and Water Quality in the Tillamook Bay Watershed: A GIS Mapping Project.* TBNEP Technical Report. Tillamook Bay National Estuary Project. Garibaldi, OR: February, 1997.

TBNEP Technical Advisory Committee. 1994. *Issue forum on biochemical water quality issues in Tillamook Bay and Watershed.* Tillamook Bay National Estuary Project Report. Garibaldi, OR: December 8, 1994.

TBNEP. 1996. *Tillamook Bay National Estuary Project.* Online. Internet. February 7, 1997. http://www.orst.edu/dept/tbaynep/.

Wiltsey, Michael R. 1990. *Tillamook Bay Watershed Bacterial Trends Assessment.* Water Quality Division, Oregon Department of Environmental Quality. Portland, Oregon. September, 1990.

Zar, Jerold. 1984. *Biostatistical Analysis.* 2nd ed. New Jersey: Simon and Schuster.

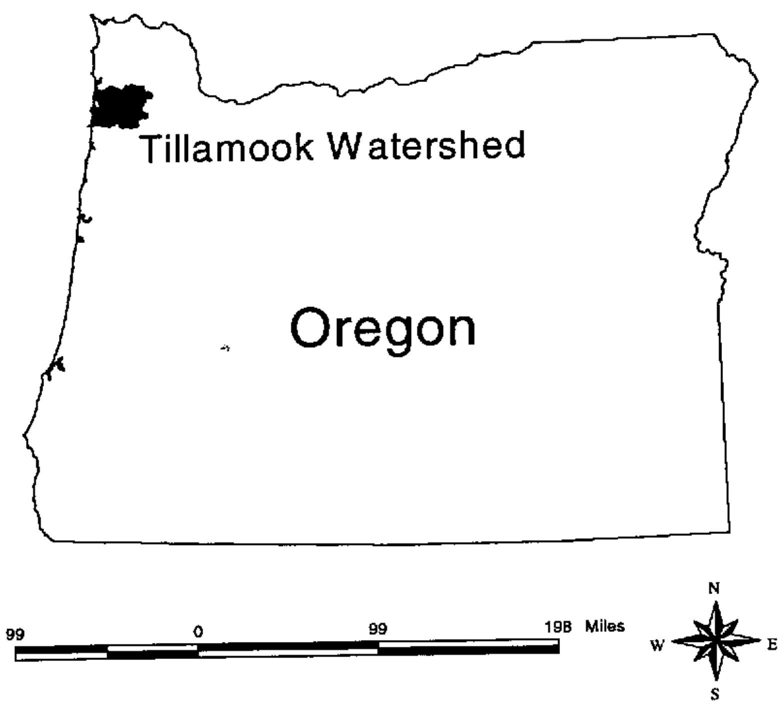

Figure 1. Location of the Tillamook Watershed in Oregon

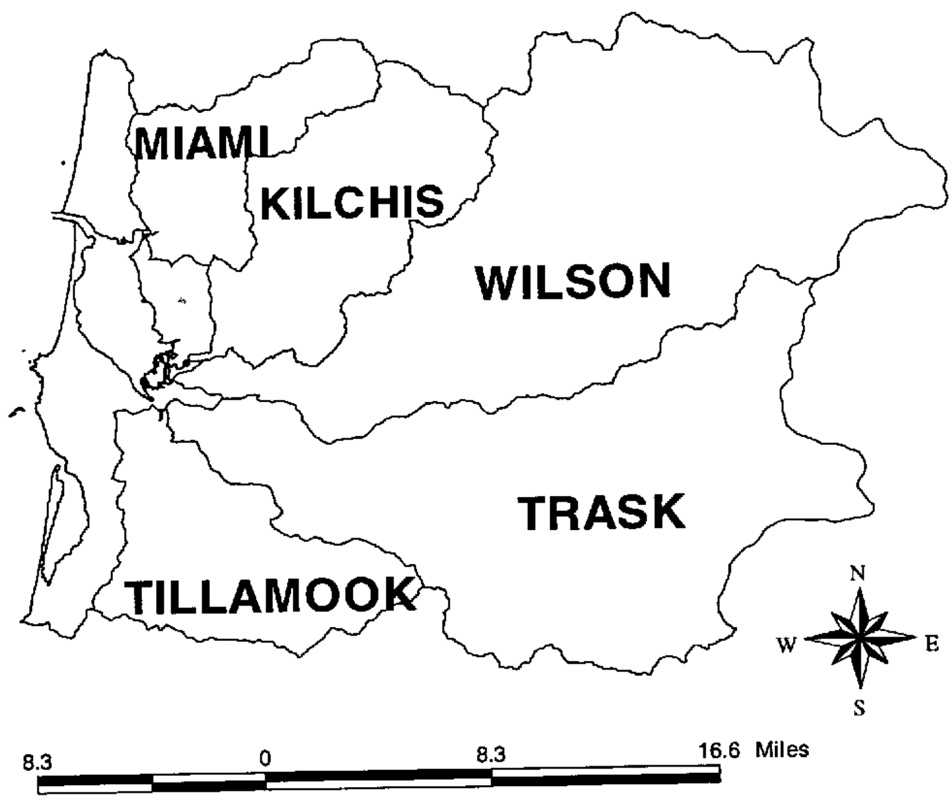

Figure 2. Location of the Miami, Kilchis, Wilson, Trask, and Tillamook subwatersheds

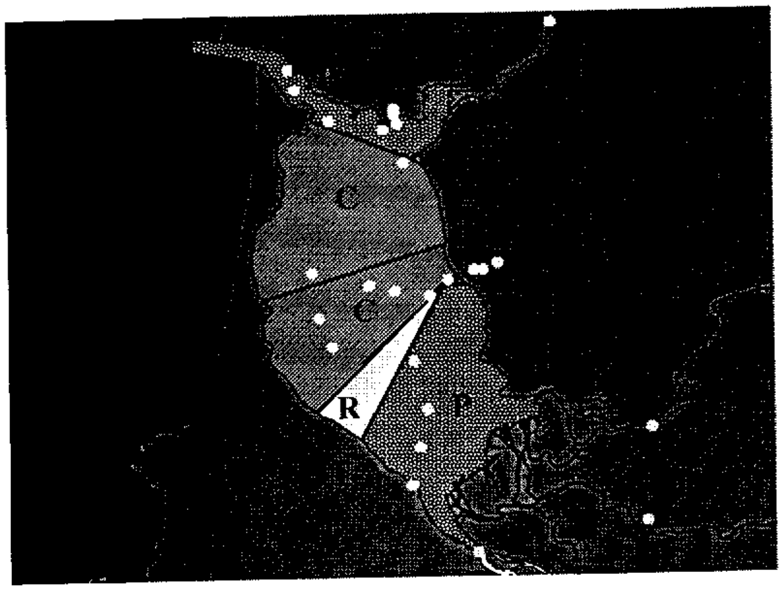

Figure 3. ODA shellfish management areas in Tillamook Bay
P = prohibited, R = restricted, C = conditional
• = DEQ water quality sampling stations for rivers and bay

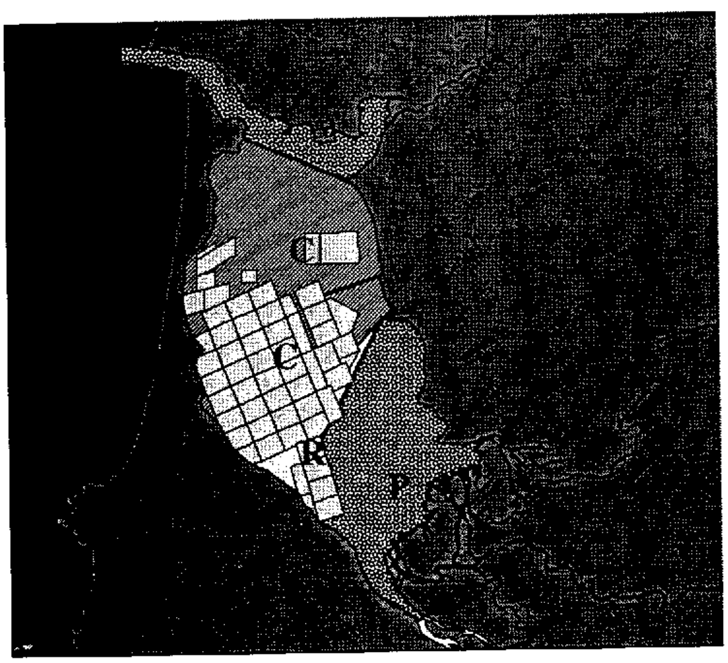

Figure 4. Oyster plat locations and shellfish management areas in Tillamook Bay
blocks = oyster plats
P = prohibited, R = restricted, C = conditional shellfish management areas

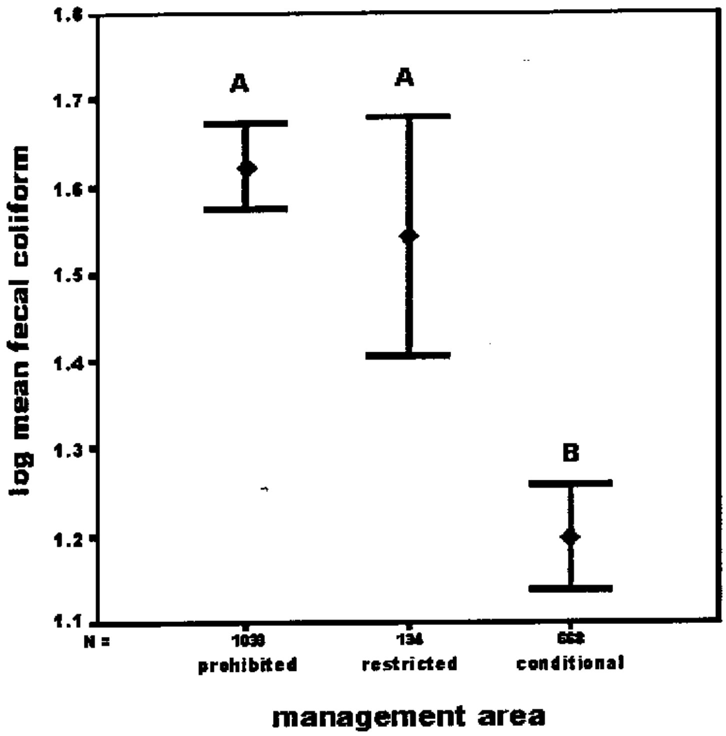

Figure 5. Comparisons of mean fecal coliform concentrations between P = prohibited, R = restricted, and C = conditional shellfish management areas in Tillamook Bay.

◊ = log mean of fecal coliform
bar = standard error bars
letters = multiple comparison test results (different letters represent significant difference)

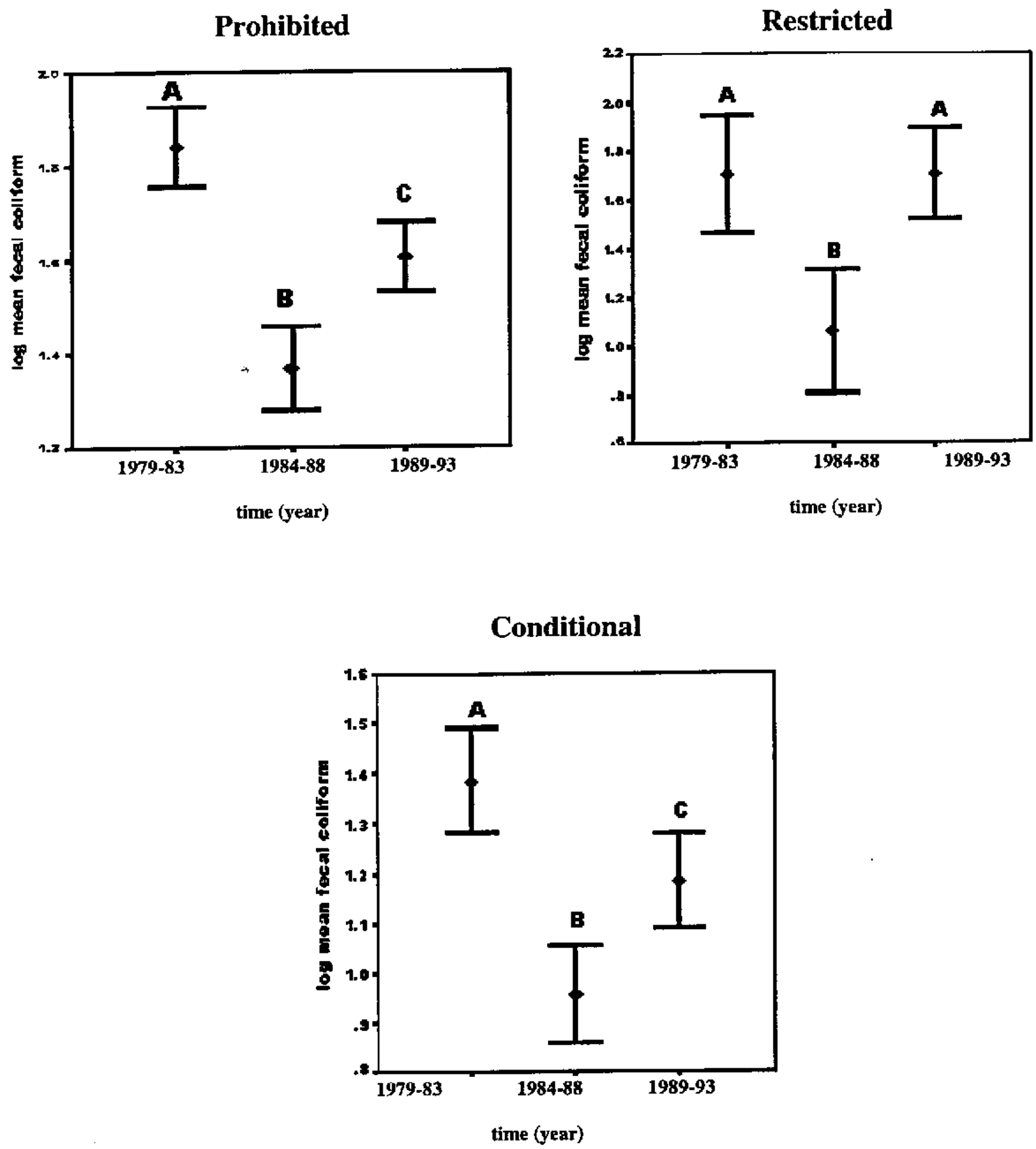

Figure 6. Comparisons of mean fecal coliform concentrations between time (1979-83, 1984-88, 1989-93) for prohibited, restricted, and conditional shellfish management areas in Tillamook Bay.

◊ = log mean of fecal coliform
bar = standard error bars
letters = multiple comparison test results (different letters represent significant difference)