Water Quality and Shellfisheries Closure in a Developing Coastal Region of North Carolina, USA: A Preliminary Overview

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ABSTRACT

South Brunswick County, North Carolina, a rapidly developing coastal region, has suffered the closure of approximately 65% of it's shellfishing waters due to elevated numbers of fecal coliforms. Some of the fecal coliform contamination may come from malfunctioning sewage treatment plants and failing septic tanks that reach densities as high as 8 per acre in some districts. Fecal coliform counts exceed the State's standard for human contact and for shellfishing in most of our monitoring locations. *Klebsiella pneumoniae* has been isolated from surface waters in some monitoring locations.

KEY WORDS: Coliforms, shellfisheries, water quality

INTRODUCTION

The coastal plain of North Carolina (NC) is characterized by gentle slopes, low elevations, a shallow water table and porous sandy soils. The area covered by wetlands is substantial; it is estimated that 95% of the wetlands in North Carolina occur in the coastal area (Wilson 1962) with open fresh water covering approximately 1,560 km^2, regularly flooded salt marshes 236 km^2 and bays and sounds covering 9,160 km^2 (Kuenzler et al. 1977).

The population centers of NC coastal counties are swelling with the influx of permanent residents and seasonal tourism. Thirty-two percent of NC's households are located in the Coastal region with an 18% increase expected by the year 2000. This increase will carry with it many of the problems associated with land disturbance, waste water treatment and increased stormwater runoff. Current disposal practices of waste water treatment via septic systems, surface water discharge of effluent and spray irrigation have contributed to pollution of NC's coastal environment (Augspurger 1989).

The State's estuarine waters are already experiencing excessive fecal coliform loadings from industrial effluent, urban and agricultural runoff, failing septic systems and marine toilets. Fecal coliform bacteria, are responsible for 22% of partial support and nonsupport designations of NC estuarine waters (NCDEHNR 1992). Total acreage closed to shellfishing in 1993 was 370,312, an increase of 11.9% from 1980 to 1993 (NCDEHNR 1994). The concentration of fecal coliform bacteria has increased with the higher concentration of septic tank installations in the coastal watershed (NCDNRCD 1982). The closure of shellfishing waters in North Carolina has been linked with both septic tank failure (McCullough 1984; Duda and Cromartie 1982, NCDNRCD 1985) and improperly installed septic systems (Carlile 1985, Grayson et al. 1982).

Package treatment plants are capable of advanced fecal coliform treatment but improper operation and maintenance have resulted in failures in some areas (Augspurger 1989). In 1989, in the 20 coastal counties defined under CAMA, 39 municipal wastewater treatment plants had NPDES permits for disposal of effluent to surface waters resulting in flows that range from 0.01 to 28 million l/day (Augspurger 1989).

Brunswick County, NC, one of the fastest growing counties in the state, is located on the southeast coastal plain directly on the North Carolina-South Carolina boarder. The year round population has increased from 35,000 in 1980 to 50,000 in 1990, (Hayes and Associates 1995). In 1998, Brunswick County had 5 minor municipal sewage treatment plants and 36 non-municipal sewage treatment plants (Russ Colby, NCDEH, personal communication 1998. Stormwater management is haphazard at best and non-existent for development of parcels under one acre.

South Brunswick County is experiencing significant growth. The region includes residential areas, apartment complexes, beach front homes, several golf course communities and a prosperous business district in the town of Calabash. The day visitor population has a significant impact on public facilities in the area (NCDEH 1997). The township of Shallotte, which includes the areas of Sunset Beach, Ocean Isle and Calabash, has experienced an increase in year-round population between 1970 and 1990 of 142% (United States Census 1990). It is estimated that approximately 12,000 tourists visit Calabash each day during the summer months (NCDEH 1997).

Sewage treatment in Shallotte Township is provided by a few package sewage treatment plants. Most domestic wastewater treatment utilizes on site septic tanks that may reach densities as high as eight per acre in some neighborhoods. Restaurants in downtown Calabash have septic tanks that must be pumped daily or weekly during the peak tourist season (NCDEH 1997). Ocean Isle Beach has a centralized sewage treatment facility.

Pollution from stormwater runoff after rainfall events is a major problem for shellfish waters in South Brunswick County and will continue to be a problem in the area without proper action (NCDEH 1997). Stormwater runoff can carry fecal coliform bacteria (MacFarlane 1997, Stevens et al. 1996) excessive nutrients (Cahoon 1996) and relatively heavy loads of suspended and dissolved solids as well as heavy metals (Johnson et al. 1998). Stormwater management in most locations uses open ditches, that remove the water from the site but do not control the quality of the runoff. Small retention ponds can be found in some housing complexes and diversion of runoff directly into existing streams and the Intracoastal Waterway (ICW) occurs.

Shellfishing covers approximately 1800 acres but 1138 acres or roughly 65% of the area is closed (NCDEH 1997). Oyster and clam production is considered to be of good commercial value and some closed areas are opened periodically on a conditional basis. Temporary closures usually occur when rainfall amounts exceed 1.5 inches within a 24 hour period.

The towns of Calabash, Sunset Beach and Brunswick County formed the South Brunswick Water and Sewer Authority (SBWSA) on June 1, 1993 to provide regional wastewater treatment and a stormwater management program for a 55 square mile area (Figure 1) in an effort to restore water quality to the region. The SBWSA 201 Facilities Plan received a 3.8 million dollar State Revolving Loan, so an Environmental Assessment document was required by and submitted to the North Carolina Division of Environmental Management on December 30, 1994. Approval of the Final Environmental Impact Statement (FEIS) is pending.

The Water Quality Assessment portion of the EIS document requires a comprehensive look at existing water quality by implementing an aggressive and thorough water quality monitoring program. SBWSA contracted with the University of North Carolina at Wilmington, Department of Biological Sciences in October 1996 to perform water quality monitoring. These data would be used to establish baseline water quality, identify problems and to measure improvements in water quality as regional sewage treatment and stormwater management practices are initiated.

Thirty six locations (Figure 1) are being monitored for chlorophyll a, total suspended solids, turbidity, pH, dissolved oxygen, salinity, total phosphate, total nitrogen, temperature and fecal coliforms. Each site is sampled every 3 weeks and all laboratory analyses follow Environmental Protection Agency guidelines for standards and quality control.

This paper will focus only on the fecal coliform data from the salt water sites located in or around the shellfishing beds and the fresh water sites that drain directly into these estuarine environments. The goal is to identify possible sources, routes and relative levels of fecal contamination.

Filter feeding shellfish can be a vector of viral and bacterial disease. The primary logic behind the fecal coliform standards set forth by the Food and Drug Administration as part of its National Shellfish Sanitation Program is to protect human health. Therefore the presence of other gram-negative bacteria in water samples will also be investigated in this paper. Sobsey et al. (1980) found enteric bacteria in oyster tissue from closed shellfishing areas and expressed the need to look in the water column and sediment .

Rainfall data has been collected for the area as an entire unit, but runoff volume calculations for each individual drainage basin are not complete. Therefore, it is assumed for this work that rain events affect each study site and subdrainage basin equally.

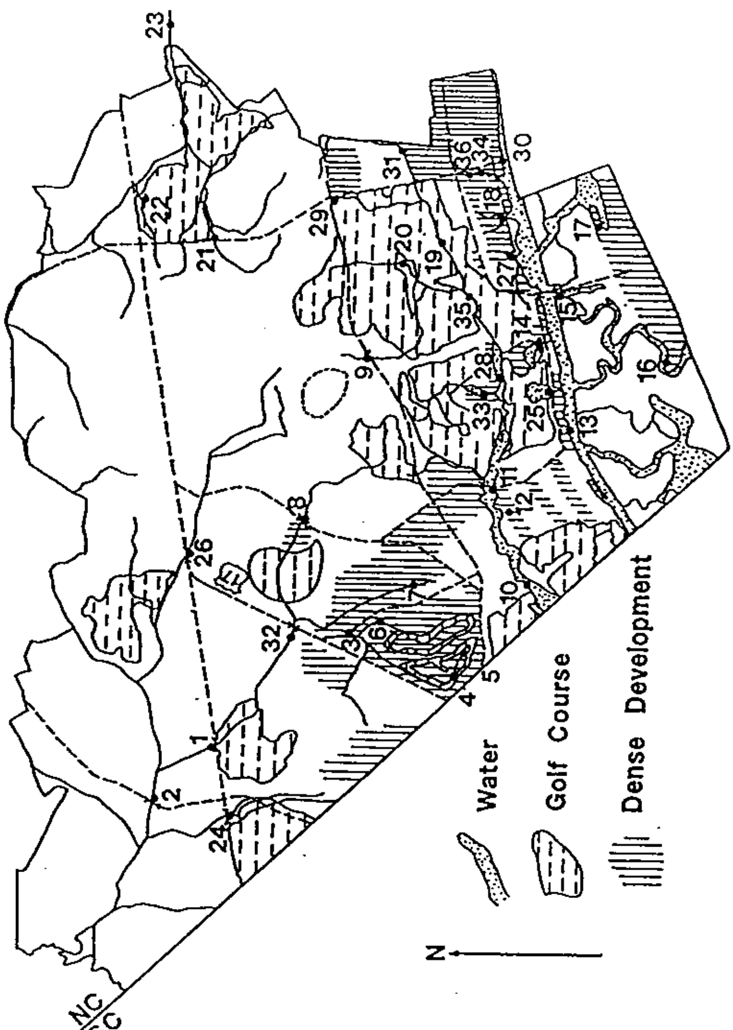

Figure 1. Water quality monitoring locations in South Brunswick County, North Carolina

MONITORING LOCATIONS

This paper uses data from the two distinct drainage basins of Calabash Creek and the ICW. Fresh water sites are sampled as close to the discharge pipe or spillway as possible. Fresh water sites include retention ponds, golf course ponds, canals and drainage ditches. Saltwater sampling sites vary in depth, flow and water exchange rates during tide changes. Salt water sites include the ICW, man made navigable canals and salt marsh areas.

The lower portion of Calabash Creek is influenced by tidal action, and includes sites 10, 11, and 12 (Figure 1). Sites 10 and 11 are in the main channel, site 12 is a located in the upper portion of a *Spartina* marsh directly down stream of a retention pond. The section of Calabash Creek above the dam at site 33 (upper northern branch) and site 28 (upper eastern branch) are freshwater lakes. Both bodies of water have homes along their shores that rely on septic systems for sewage treatment. Samples are taken in the lakes, at the spillways.

The mainland side of the ICW is skirted by larger, well kept homes; the island side of the ICW is mud flat and salt marsh. Sites located in the ICW include sites 13, 15, 16, 17 and 30. Site 15 has relatively the highest flushing rate for the salt water sites. Site 16 is a shallow creek in *Spartina* marsh and site 17 is in a navigable canal. Both site 16 and 17 are characterized by poor water exchange during tide changes.

Fresh water sites that drain directly into the ICW include sites 14, 18, 25, 27, 34 and 36. Site 25 and site 14 are small lakes surrounded by homes using septic systems for sewage treatment. Site 25 also has a small private sewage package plant situated directly behind it with a subsurface drainage field. Site 18, 27, 34 and 36 are located directly in a canal that runs parallel to the ICW. These sites are flanked by traditional homes or older mobile homes all on septic systems.

METHODS

The membrane filtration method (MF-C) was used for the determination of fecal coliform numbers (APHA 1995). Six plates were prepared from each grab sample, three, 10ml plates, one, 0.1ml plate, one, 1.0ml plate and one, 100ml plate typically. Mean and standard deviations were determined from the three, 10ml plates. Colonies from fecal coliform plates that did not meet the criteria for identification as positive for the fecal coliform count were randomly chosen and isolated from November 1997 to August of 1998. API 20 E strips (bioMerieux Vitek, Inc.) were used to identify some of the isolates collected.

RESULTS

Fecal coliform samples were collected from 10/22/96 to 8/20/98. A total of 191 values from the salt water sites and a total of 138 values from the fresh water sites were determined. Among the salt water samples 77% exceeded the shellfishing standard of 14 cfu/100 ml (Figure 2). Site 17 had one relatively high count of 407 cfu/100 ml. Among the fresh water samples 54% exceeded the 14 cfu/100 ml shellfishing standard for fecal coliforms. A single event at site 25 yielded a fecal coliform count of 19,750 cfu/100ml.

A total of 39 isolates were chosen from the fecal coliform plates for API testing. Of these, 26 were determined to be either *E. coli* or a no match result. A qualitative look at the results shows *Klebsiella pneumoniae* from site 28, 33 and 36 during the warmer summer months. *K. pneumoniae* was not found in isolates taken from the salt water monitoring locations. A single isolate of a *Citerobactor* sp. was found at site 12 and a single isolate of *Pseudomonas* sp. was found at site 27.

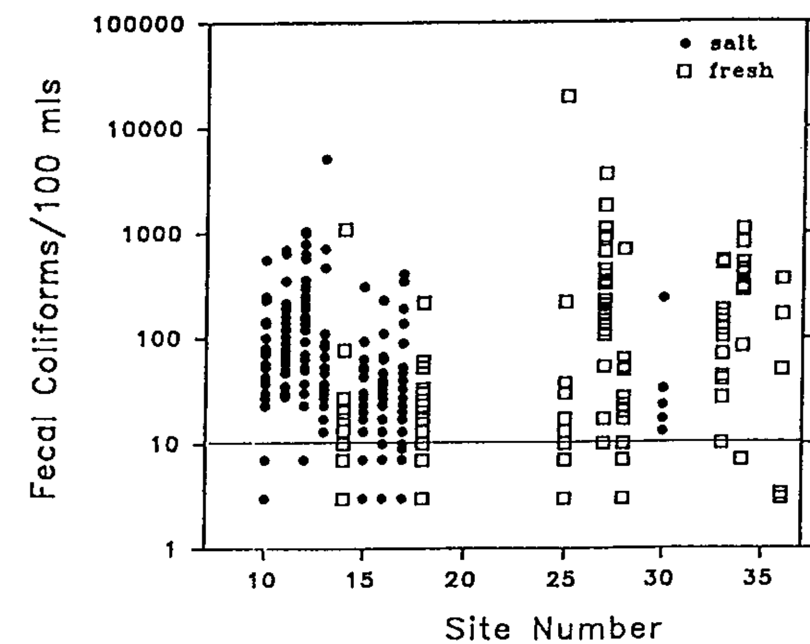

Figure 2. Fecal coliform values (mean ± std. dev.) for salt water and fresh water sites associated with shellfishing areas. Horizonal line marks the 14 CFU/100 ml.

SUMMARY

Fresh water discharging into estuarine areas does appear to carry excessive loads of fecal coliform bacteria. Most of the freshwater discharging into shellfishing areas exceeds the state standard of 14 cfu/100ml, therefore it is not surprising to find fecal coliform levels in most of the saltwater sites that exceed acceptable levels.

Calabash Creek is receiving fecal contamination from site 33 and 12. Storm water infiltration and consequent over-flow from septic tanks surrounding areas must be considered as a possible source of the fecal coliform. Site 28 has slightly lower fecal coliform numbers and is frequented by several species of water bird that may be contributing fecal coliforms at this location.

Reports of septic tank failure behind sites 18, 27 and 34 make them a likely source of the fecal contamination for the ICW that may not necessarily be linked entirely with stormwater runoff. The episodal event that occurred at site 25 indicates that fecal contamination from that site may not always be associated with stormwater runoff as well. Investigation of the area by enforcement officials revealed a "blow out" in one of the sub-surface drain field lines used by the sewage treatment plant located directly behind site number 25. Sites 16, 17, 28 and 33 are primary storm water outfall locations for the SBWSA planning area. These data indicate that they are a significant non-point source for fecal contamination. Surface runoff and possible septic tank discharge via ground water must be considered as a source for these sites.

Klebsiella spp can be human pathogens, but they can also occur naturally in the environment. We have found *K. pneumoniae* and *K. oxytocia* throughout the year in others sections of the planning area, particularly along the entire length of a stream that receives effluent from a private sewage treatment plant. *Klebsiella* spp. have been reported to have a longer survival time in the environment than other coliform bacteria (Sjogren and Gibson 1981). Warmer summer temperature may be permitting longer survival time of *K. pneumoniae* in the sites skirting the ICW. It is possible that the isolates from sites 28, 33 and 36 have been introduced into the surface waters from area septic systems.

Fecal coliform standards have been set to help define the possible contamination of shellfishing waters by human pathogens. *K. pneumoniae* can be an opportunistic pathogen with significant resistance to environmental stress, antibiotics (McKeon et al. 1995) and chlorination (Power et al. 1997, Andersen 1993). It's presence can a human health concern.

CONCLUSION

Our data clearly indicate fecal coliform contamination from fresh water sources that can be episodal in nature and/or related to storm water runoff. Direct contamination from septic tanks and malfunctioning sewage treatment package plants are most likely the primary source. Shellfishing waters in the area are routinely closed after heavy rains of 1.5" or more. Non-storm related events, like the sewage line break-out at site 25 suggest the influx of high levels of fecal coliform contamination of shellfishing areas may occur between storm events.

Shellfisheries closures due to fecal coliform contamination from septic tank failure are not isolated to the SBWSA planning area. Failing septic systems have been found to be a primary source for fecal coliforms in the lower Chesapeake Bay (Erkenbrecher 1981) and in Tillamook Bay, Oregon where it was estimated that 15 to 20 percent of fecal input came from septic systems (Glendening 1981).

A regional wastewater treatment facility and an aggressive stormwater management scheme can only improve water quality in the SBWSA planning area. SBWSA is in the planning stage of developing a Storm Water Quality Management Program for its service area. The program will address existing water quality problems and impacts of future growth on surface waters. Best Management Practices (BMPs) will be developed and work from a pollution prevention type of approach. On-site septic system inspections, development of sedimentation and erosion control ordinances and provisions for a citation procedure to handle violations are to be included. Natural vegetative buffers along streams and other bodies of water will be set aside to provide filtration of sediment, nutrients and bacteria from stormwater runoff before it enters water ways.

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