Baseline Report on Bald Head Creek Water Quality

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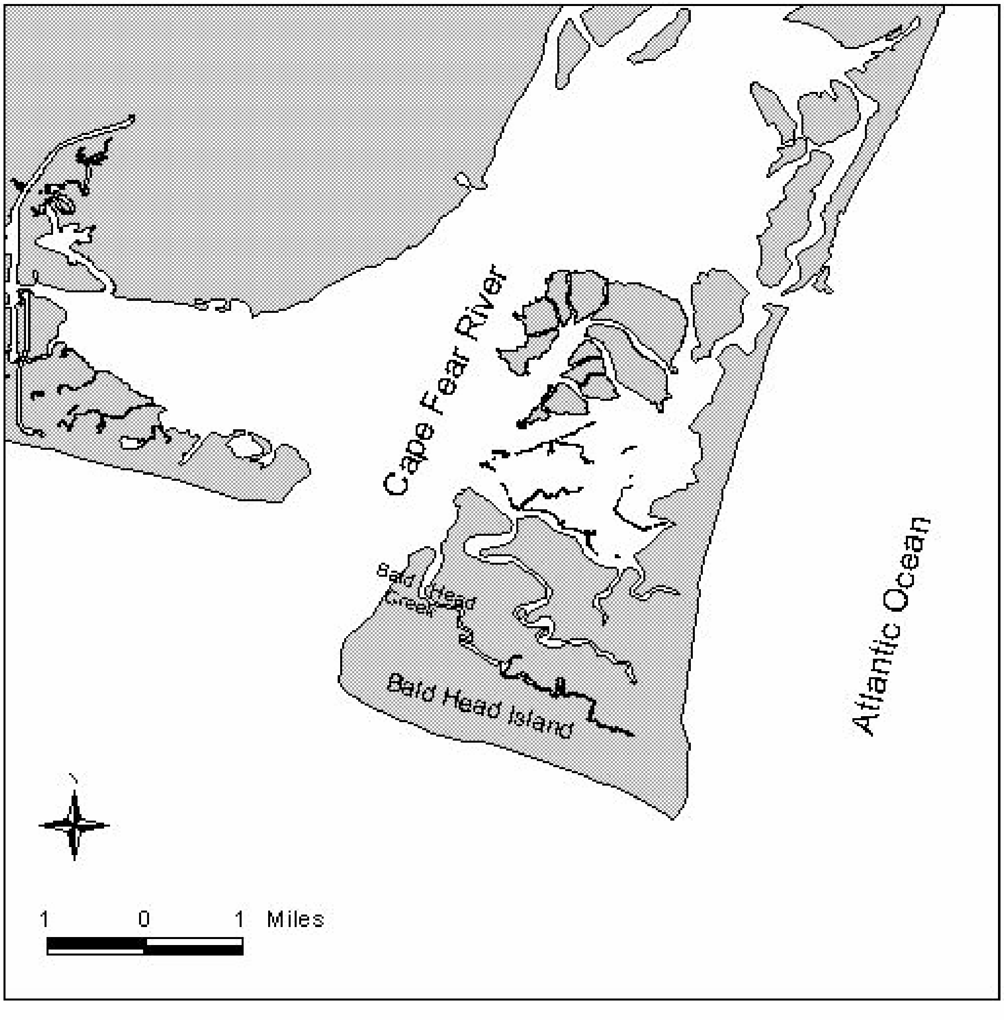

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Introduction

Bald Head Creek is a brackish tidal creek located along the southwest side of Bald Head Island, in southeastern North Carolina. Bald Head Island is on the terminal portion of Cape Fear, the southernmost cape in North Carolina. Bald Head Island is located on the eastern shore of the Cape Fear River estuary immediately before it enters the Atlantic Ocean, and while considered an island, the shoreline is technically connected to the mainland at Fort Fisher since New Inlet closed in 1999. Bald Head Creek is a second order stream that begins in a maritime forest and terminates in the lower Cape Fear Estuary (Fig. 1). It is approximately 6 km (3.7 miles) long, and separates Bald Head Island from its central and northern portions, Middle Island and Smith Island. Bald Head Creek was closed to shellfishing due to excessive fecal coliform counts in 1992 and has remained closed to shellfishing since that time (LMG 2004).

The Village of Bald Head Island is largely recreational with a population that can range from 100 during winter to 5,000 in the summer (NCDEH 2001). Most of the residents are served by a tertiary wastewater treatment plant with a 200,000 GPD capacity, and treated and chlorinated effluent is discharged into an infiltration pond on the golf course (NCDEH 2001). There are some septic systems in use in the Bald Head Creek watershed.

The elevated fecal coliform bacteria counts in the creek were apparently due to non-point source pollution. North Carolina Shellfish Sanitation has stated that a dye study indicated that the septic systems on the island were not contributing fecal coliforms to groundwater discharge (NCDEH 2001). That study also concluded that wildlife was the most likely source of fecal coliform contamination in Bald Head Creek, compounded by the low rates of tidal flushing. A tidal exchange rate dye study conducted by Jason Hales of the University of North Carolina at Wilmington in 1998 and 1999 found that percent exchange rates varied between 18% and 33%, which is low compared with other area tidal creeks (Hales 2001).

Based on a study performed in Futch Creek, located in northern New Hanover County along the Atlantic Intracoastal Waterway (Mallin et al. 2000a), creek mouth dredging has been suggested as a means of reducing fecal coliform pollution. This is based on the fact that higher salinity kills fecal coliform bacteria more quickly than fresh or low salinity waters (Evison 1988), and the potential that dredging will also improve dilution of the pollutants by allowing greater tidal exchange. The Aquatic Ecology Laboratory at the UNC Wilmington Center for Marine Science also performed a water quality study of the water bodies located in and near Mason Inlet before the dredging and moving of that inlet. That study concluded that water quality, including fecal coliform bacteria concentrations, was good before Mason Inlet dredging and remained so following inlet movement (Mallin et al. 2003a). In 2003 the Village of Bald Head requested permits to dredge the mouth of Bald Head Creek to improve water quality. In 2003-2004 the UNCW Aquatic Ecology Laboratory performed a baseline water quality study on Bald Head Creek to gather information relevant to the proposed dredging and construction activity at the mouth of the creek.

Methods

Samples were collected at four stations on the creek. Station A was located off a private dock near the creek mouth, station B was off the old Boat House Dock on the south side of the creek, station C was off a dock on the north side of the creek about four km upstream from the mouth of the creek, and station D was off a small dock in the creek headwaters (Table 1; Fig. 1). Eight collections were made, during June, July, August, September, October (two collections), November and December 2003 and one collection in January 2004. Samples were collected at or just after high tide so comparisons could be made with data from a project analyzing urbanized tidal creeks along the Atlantic Intracoastal Waterway (ICW) in New Hanover County (Mallin et al. 2004a).

Field parameters (water temperature, pH, dissolved oxygen, turbidity, salinity, and conductivity) were measured at each site using a YSI 6920 Multiparameter Water Quality Probe (sonde) linked to a YSI 650MDS display unit. The instruments were calibrated prior to each sampling trip to ensure accurate measurements.

For nitrate+nitrite (hereafter referred to as nitrate) and orthophosphate assessment, three replicate acid-washed 125 mL bottles were placed ca. 10 cm below the surface, rinsed, filled, capped, and stored on ice until processing. In the laboratory the triplicate samples were filtered simultaneously through 25 mm Gelman A/E glass fiber filters (nominal pore size 1.0 micrometer) using a manifold with three funnels. The pooled filtrate was stored frozen until analysis. Samples for ammonium were collected in duplicate, field-preserved with phenol, stored on ice, and analyzed in the laboratory according to the methods of Parsons et al. (1984). Chlorophyll *a* concentrations were determined from the filters used for filtering samples for nitrate+nitrite and orthophosphate analyses. All filters were wrapped individually in aluminum foil, placed in an airtight container with dessicant and stored in a freezer. During the analytical process, the glass fiber filters were separately immersed in 10 mL of a 90% acetone solution. The acetone was allowed to extract the chlorophyll from the filter for 18-24 hours. The extracted material was then analyzed for chlorophyll *a* concentration using a Turner AU-10 fluorometer. This method uses an optimal combination of excitation and emission bandwidths that reduces the errors inherent in the acidification technique (Welschmeyer 1994).

Bacteria samples were collected by lowering pre-autoclaved 500 ml glass containers about 10 cm below the water surface, facing into the current. Samples were kept on ice in coolers until processing at the laboratory, within six hours of collection. The method used in this study to assess fecal coliform concentrations was the membrane filtration method (mFC), described in Standard Methods (APHA 1995). This method utilizes an elevated temperature incubation to distinguish fecal coliforms from the total coliform group. Total suspended solids, or TSS, were collected in 500 mL containers, placed on ice, and analyzed using Method 2540-D according to Standard Methods (APHA 1995).

Additionally, YSI 6920 instruments were deployed in-situ at docks at Stations A and B in order to obtain short interval salinity data over two diel cycles (August 2003 and January 2004). If a dredging permit is issued, this will be repeated during a similar tidal phase following construction to determine if salinity and other parameters change following dredging.

Table 1. Locations of sampling sites in Bald Head Creek

Site	Location
BH-A	Off first private dock on Tanbark Court near mouth of Bald Head Creek
BH-B	Off old boathouse dock at end of Boat House Path
BH-C	Off public floating dock on north shore of creek, accessible from Cape Creek Road
BH-D	Off small community dock at headwaters of creek adjacent to Cape Creek Road just after the terminus of South East Beach Road

Results and Discussion

Water Temperature

Water temperature at all four sites averaged from 21-22 ^{o}C for all sampling events. There were no incidents of freezing and no extremely warm periods (maximum of 31.6 ^{o}C).

Salinity

Based on samples collected in conjunction with the chemical and biological parameters, salinities were polyhaline (polyhaline ranges from 16-25 ppt) on average at all four sites (Table 2; Fig. 2), with a general decrease from the mouth (29.2 ppt) to the headwaters station BH-D (21.2 ppt). We emphasize that these samples were collected on the outgoing tide, shortly after high tide, thus salinities during sample collection represent near maximum salinities normally experienced at the sample sites. Average and minimum (14.8 ppt) salinities at the uppermost station BH-D indicate that there is only minor freshwater influence into this creek from the watershed.

Diel salinity data were every 30 minutes are available from BH-A and BH-B, from August 19-20, 2003 and from December 17-18, 2003). December 2003 data show that salinity ranged from 14.5 ppt at low tide to 29.1 ppt at high tide near the creek mouth at BH-A, while there was a narrower range of 15.3 ppt to 19.4 ppt farther upstream at BH-B (Fig. 3). Salinities collected during the diel measurement in August 2003 at BH-A were considerably lower, ranging from 10.9 at low tide to 26.5 ppt at high tide, while values at BH-B ranged from 10.0 ppt at low tide to 15.3 at high tide. The August 2003 diel study was conducted during a period of high river discharge when salinities were lower than normal in the Cape Fear Estuary. The river appears to play the major role in regulating creek salinity, as opposed to freshwater inputs to the headwaters.

Dissolved oxygen

Dissolved oxygen concentrations in the creek were typical of area tidal creeks, with highest concentrations during winter and lowest during summer. Concentrations less than the NC State standard of 5 mg/L were seen twice at BH-C and three times at BH-D, during the June to September period, with a minimum level of 3.7 mg/L at BH-D in September (Table 2).

Dissolved oxygen concentrations at Channel Marker 18 in the lower Cape Fear Estuary near Southport were slightly higher than those at BH-A, with a mean of 8.1 mg/L (Mallin et al. 2003b).

Turbidity

There was a pattern of highest turbidities at the mouth and uppermost creek stations, with somewhat lower turbidities at the two mid-creek stations (Table 2). However, there was only one incident when turbidity exceeded the NC State standard of 25 NTU (33 NTU at BH-D on October 29, 2003). Average 2002-2003 turbidity concentrations at Channel Marker 18 in the lower Cape Fear Estuary near Southport were identical to those at BH-A (Mallin et al. 2003b). Thus, we suspect that turbidity enters the creek from the river, and is also a function of eroded particles from soils in the headwaters of Bald Head Creek.

Total Suspended Solids (TSS)

TSS concentrations were quite consistent across the four sampling sites (Table 2). Concentrations were slightly higher at the creek mouth (BH-A), possibly a result of tide and river current activity resuspending and moving sand. The river proper is probably not an important source of TSS, as average 2002-2003 TSS concentrations at Channel Marker 18 were 13 mg/L (Mallin et al. 2003b), considerably lower than those at BH-A.

Ammonium-N

Ammonium concentrations presented a pattern of lowest values nearest the river and highest values in the headwaters (Table 2). None of the values appeared to be excessive, however. Ammonium concentrations at BH-A, BH-B, and BH-C were in the same range as concentrations in Futch, Howe, and Hewletts Creeks along the ICW, but concentrations at BH-D were somewhat higher (Mallin et al. 2004b). Ammonium is a decomposition product; thus, the higher values in the headwaters may reflect decomposition of accumulated biotic material in that area, retained because of less tidal flushing than is seen in the tidal creeks along the ICW (Hales 2000).

Nitrate-N

Nitrate concentrations presented an unusual, but consistent pattern of highest concentrations in the mid-creek stations and lower concentrations at the creek mouth, with lowest levels upstream at BH-D (Table 2; Fig. 3). Average nitrate concentrations at Channel Marker 18 in the river were 116 μg/L, considerably greater than those at BH-A. However, concentrations at BH-A were much higher than concentrations normally found at tidal creek mouth stations in the urbanized creeks along the ICW, but concentrations at BH-D were far lower than upstream nitrate concentrations in the urbanized creeks (Mallin et al. 2004b). Nitrate is a common signal of human impact, and is derived largely from lawn, garden, and golf course fertilizers, as well as domestic and wild animal manure. The concentrations and distribution of nitrate in Bald Head Creek shows little evidence of surface runoff, in contrast to the urbanized tidal creeks. The peak levels in mid-creek are unique to area creeks, and may reflect groundwater inputs into that region. Evidence for nitrate loading from groundwater has been documented from Futch Creek springs (Roberts 2000). Nitrate moves easily through porous coastal soils. Potential sources for the nitrate in Bald Head Creek may include golf course fertilizers or inputs from septic systems. However, State regulators did not find malfunctioning septic systems in terms of fecal coliform inputs (NCDEH 2001), and most residences are presently hooked into the wastewater treatment plant. Most human development along the creek is presently located in the area from mid-creek downstream to the creek mouth. The upstream areas are being developed as we write this report. Regardless, the present nitrate inputs do not seem to be problematic, as chlorophyll *a* concentrations were generally low to moderate with no algal blooms noted in our study (see below).

Orthophosphate-P

Like ammonium, orthophosphate concentrations displayed a pattern of increasing values upstream (Table 2; Fig. 3). This would indicate that the primary phosphorus source is in the headwaters region; a similar situation to what is seen in the urbanized New Hanover County tidal creeks (Mallin et al. 2004b). Orthophosphate concentrations in Bald Head Creek were generally low. Mean 2002-2003 orthophosphate concentrations at Channel Marker 18 in the Cape Fear River were 14 µg/L, very similar to concentrations at BH-A and BH-B. Orthophosphate concentrations in the urbanized New Hanover County tidal creeks were somewhat lower than those of Bald Head Creek, particularly in the headwaters areas (Mallin et al. 2004).

Chlorophyll *a*

Average chlorophyll *a* concentrations ranged from 2.5 to 3.4 µg/L among the four sites, with no algal blooms recorded (Table 2). These values represent low to moderate chlorophyll *a* concentrations compared with estuarine situations in general (Bricker et al. 1999). Average 2002-2003 chlorophyll *a* concentrations at Channel Marker 18 were 4.0 µg/L (Mallin et al. 2003b), very similar to those at BH-A. However, the spatial pattern and magnitudes of Bald Head Creek's chlorophyll *a* concentrations vary considerably compared with New Hanover County's urbanized tidal creeks. Chlorophyll *a* concentrations at the creek mouth stations of the urbanized tidal creeks were similar to those of Bald Head Creek (Mallin et al. 2004b), but upstream chlorophyll *a* concentrations in the urbanized creeks were much higher. Average high tide chlorophyll *a* values from 1993-2001 in upstream stations in the urbanized creeks were 8.1, 31.3, and 16.1 µg/L in Futch, Howe, and Hewletts Creeks, respectively (Mallin et al. 2004b). Thus, the higher watershed nutrient loading in the urbanized tidal creeks has a marked effect on algal bloom formation when compared to the less developed Bald Head Creek watershed.

Fecal Coliform Bacteria

Fecal coliform bacteria concentrations presented a pattern of lowest geometric mean concentrations at the two stations closest to the river (BH-A and BH-B), with concentrations increasing toward the headwaters (Table 2; Fig. 2). Stations BH-C and BH-D both maintained geometric means that exceeded levels considered safe for shellfishing by Federal and North Carolina authorities (USFDA 1995; NCDEHNR 1996). Based on a defined sampling scheme, NC Shellfish Sanitation also considers waters unfit for shellfishing if the concentration of 43

CFU/100 mL is exceeded on more than 10% of sampling occasions. While the approximate monthly sampling scheme we employed was not the same sampling regime as performed by the regulatory agencies, for informational purposes we note that BH-A, BH-C, and BH-D all exceeded the 10% mark (Table 2). Since our samples were generally taken at or just after high tide, these fecal coliform counts are likely conservative (low in relation to low tide samples). This is because in area tidal creeks minimum fecal coliform counts are normally found at high tide and maximum counts at low tide (Mallin et al. 1999).

As a comparison, fecal coliform counts at Channel Marker 18 in the lower Cape Fear Estuary were slightly lower, with a geometric mean of 1 CFCU/100 mL and a mean of 6 CFU/100 mL (Mallin et al. 2003b). When compared with urbanized tidal creeks along the ICW (also sampled at or near high tide), counts near the creek mouths were similar; however, counts in the headwaters areas of the urbanized creeks were 2-10X higher than those in the Bald Head Creek headwaters (Mallin et al. 2000b). The exception to this was Futch Creek, the watershed of which presently has comparatively low development. Geometric mean concentrations in upper Futch Creek for 2002-2003 were 17 CFU/100 mL, and in less-developed Foy Creek only 5 CFU/100 mL (Mallin et al. 2004a). The generally low fecal coliform counts in Bald Head Creek (creek all-station combined geometric mean 13 CFU/100 mL), even in the headwaters, provides further evidence to recent research (Mallin et al. 2000b; Holland et al. 2004) that demonstrated how low impact development, especially low impervious surface coverage, allows minimal anthropogenic tidal creek pollution.

Conclusions

At present, Bald Head Creek drains a watershed that appears to have minimal human impact on the creek. There appears to be low surface runoff of pollutants into the creek, and salinities appeared to be controlled primarily by Cape Fear River inputs. During this study chlorophyll *a* was low to moderate and algal blooms were not detected. Nutrients were low to moderate, relative to other area tidal creeks. There were somewhat elevated nitrate concentrations in the mid-creek stations, with an unknown source. However, as mentioned, algal blooms were not seen.

Fecal coliform counts at all sites in Bald Head Creek were well within the standards for human contact set by the NC Division of Water Quality. However, except for Station BH-B, the creek fecal coliform counts exceeded those considered safe for shellfishing. Since we conclude that human impacts to the creek from surface runoff are presently minimal, we agree with the suggestion by Shellfish Sanitation that fecal coliform inputs to the creek are primarily from local wildlife, and retained because of the low tidal exchange rates documented by Hales (2000). Creek mouth dredging is likely to improve tidal exchange rates in this situation.

We recommend that the Village of Bald Head Island obtain good estimates of creek watershed impervious surface coverage. An analysis conducted on five urbanizing tidal creeks (Bradley, Futch, Howe, Hewletts and Pages) over a four-year period produced a regression equation that predicted the geometric mean fecal coliform abundance (FC) at high tide for all stations combined in a tidal creek using percent watershed impervious coverage (%IMP).

$$FC = 5.4(\%IMP) - 29, r^2 = 0.95, p = 0.005$$

This equation later accurately predicted fecal coliform abundance in Whiskey Creek (Mallin et al. 2001) and was verified in Brunswick County creeks by Dr. Larry Cahoon of UNCW. Since current impervious coverage estimates are not available, we roughly estimated the amount of potentially developable land in the watershed using planimetry and a satellite photograph. Subtracting the creek and associated wetlands, the Reserve, and the golf course area, and assuming a maximum impervious coverage of 25% of the remainder, we estimated that 12% of the watershed could potentially receive impervious coverage. This could lead to significant future increases in fecal coliform loading to the creek. To ensure minimal bacterial contamination of the creek in the future we recommend that the Village of Bald Head Island make efforts to keep total impervious coverage of the watershed to 10% or less, and vigorously enforce the existing domestic pet waste ordinance.

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References

APHA. 1995. Standard Methods for the Examination of Water and Wastewater. 19th ed. American Public Health Association, Washington, D.C.

Bricker, S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando and D.R.G. Farrow. 1999. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries.* NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science. Silver Spring, MD, 71 pp.

Evison, L.M. 1988. Comparative studies on the survival of indicator organisms and pathogens in fresh and sea water. Water Science and Technology 20:309-315.

Hales, J. 2000. Tidal exchange in coastal estuaries: effects of development, rain and dredging. M.S. Thesis, Program in Marine Science, University of North Carolina at Wilmington, Wilmington, N.C. 46 pp.

Holland, A.F., D.M. Sanger, C.P. Gawle, S.B. Lerberg, M.S. Santiago, G.H.M. Reikerk, L.E. Zimmerman and G.I. Scott. 2004 Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298:151-178.

LMG. 2004. Environmental Assessment, Bald Head Creek Shoal Dredging Project. Prepared for The Village of Bald Head Island, Bald Head Island, N.C., by Land Management Group, Inc., Wilmington, N.C.

Mallin, M.A., E.C. Esham, K.E. Williams and J.E. Nearhoof. 1999. Tidal stage variability of fecal coliform and chlorophyll *a* concentrations in coastal creeks. Marine Pollution Bulletin 38:414-422.

Mallin, M.A., L.B. Cahoon, R.P. Lowe, J.F. Merritt, R.K. Sizemore and K.E. Williams. 2000a. Restoration of shellfishing waters in a tidal creek following limited dredging. Journal of Coastal Research 16:40-47.

Mallin, M.A., K.E. Williams, E.C. Esham and R.P. Lowe. 2000b. Effect of human development on bacteriological water quality in coastal watersheds. Ecological Applications 10:1047-1056.

Mallin, M.A., S.H. Ensign, M.R. McIver, G.C. Shank and P.K. Fowler. 2001. Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. Hydrobiologia 460:185-193.

Mallin, M.A., H.A. CoVan and D.H. Wells. 2003a. *Water Quality Analysis of the Mason inlet Relocation Project*. CMS Report 03-02. Center for Marine Science, University of North Carolina at Wilmington, Wilmington, N.C.

Mallin, M.A., M.R. McIver, H.A. Wells, M.S. Williams, T.E. Lankford and J.F. Merritt. 2003b. *Environmental Assessment of the Lower Cape Fear River System, 2002-2003.* CMS Report No. 03-03, Center for Marine Science, University of North Carolina at Wilmington, Wilmington, N.C.

Mallin, M.A., L.B. Cahoon, M.H. Posey, V.L. Johnson, T.D. Alphin, D.C. Parsons and J.F. Merritt. 2004. *Environmental Quality of Wilmington and New Hanover County Watersheds, 2002-2003*. CMS Report 04-01, Center for Marine Science, University of North Carolina at Wilmington, Wilmington, N.C.

Mallin, M.A., D.C. Parsons, V.L. Johnson, M.R. McIver and H.A. CoVan. 2004. Nutrient limitation and algal blooms in urbanizing tidal creeks. Journal of Experimental Marine Biology and Ecology 298:211-231.

NCDEH. 2001. Report of Sanitary Survey, Cape Fear River Area, Areas B2 and B3. Shellfish Sanitation Section, North Carolina Division of Environmental Health, Morehead City, N.C.

NCDEHNR. 1996. Water Quality Progress in North Carolina, 1994-1995, 305(b) Report. Report No. 96-03. North Carolina Department of Environment, Health, and Natural Resources, Division of Water Quality. Raleigh, N.C.

Roberts, T.L. 2002. Chemical constituents in the Peedee and Castle Hayne aquifers: Porter's Neck area, New Hanover County, North Carolina. M.S. Thesis, Department of Earth Sciences, University of North Carolina at Wilmington, Wilmington, N.C. 63 p

USFDA. 1995. Sanitation of shellfish growing areas. National Shellfish Sanitation Program Manual of Operations, Part 1. United States Department of Health and Human Services, Food and Drug Administration, Office of Seafood, Washington, D.C.

Welschmeyer, N.A. 1994. Fluorometric analysis of chlorophyll *a* in the presence of chlorophyll *b* and phaeopigments. Limnology and Oceanography 39:1985-1993.

Table 2. Water quality data by station for Bald Head Creek, June 2003-January 2004. Data as mean ± standard deviation, range. Fecal coliform bacteria as geometric mean and range.

Parameter	BH-A	BH-B	BH-C	BH-D
Temperature (°C)	21.2±7.0 9.6-28.8	21.0±7.6 8.3-28.8	21.2±8.4 8.2-29.8	21.7±9.1 8.0-31.6
Salinity (ppt)	29.2±4.2 22.1-33.1	24.7±4.2 14.4-30.1	23.1±4.2 16.4-27.8	21.2±4.2 14.8-27.9
Dissolved oxygen (mg/L)	7.6±1.5 5.7-10.9	7.5±2.0 5.2-11.9	7.1±2.3 4.2-11.9	6.6±2.2 3.7-10.2
Turbidity (NTU)	12±6 4-25	8±2 5-13	9±4 5-19	15±8 4-33
Total suspended solids (mg/L)	36±16 15-67	27±10 17-49	29±16 16-64	28±18 5-64
Ammonium-N (µg/L)	25±10 11-40	34±8 16-46	42±18 15-81	61±28 18-114
Nitrate-N (µg/L)	52±28 19-115	90±40 30-168	71±26 32-103	31±15 13-52
Orthophosphate-P (µg/L)	12±7 6-27	17±8 10-30	18±6 12-29	33±18 14-60
Chlorophyll *a* (µg/L)	3.4±1.5 0.2-4.7	2.5±1.5 0.1-4.6	3.0±2.5 0.2-7.0	2.9±2.4 0.0-5.8
Fecal coliform bact. (CFU/100 mL)	6	6	19	46
Range (minimum-maximum)	1-78	2-22	6-130	11-1090
% of samples > 14 CFU/100 mL	25%	13%	50%	88%
% of samples > 43 CFU/100 mL	13%	0%	25%	38%

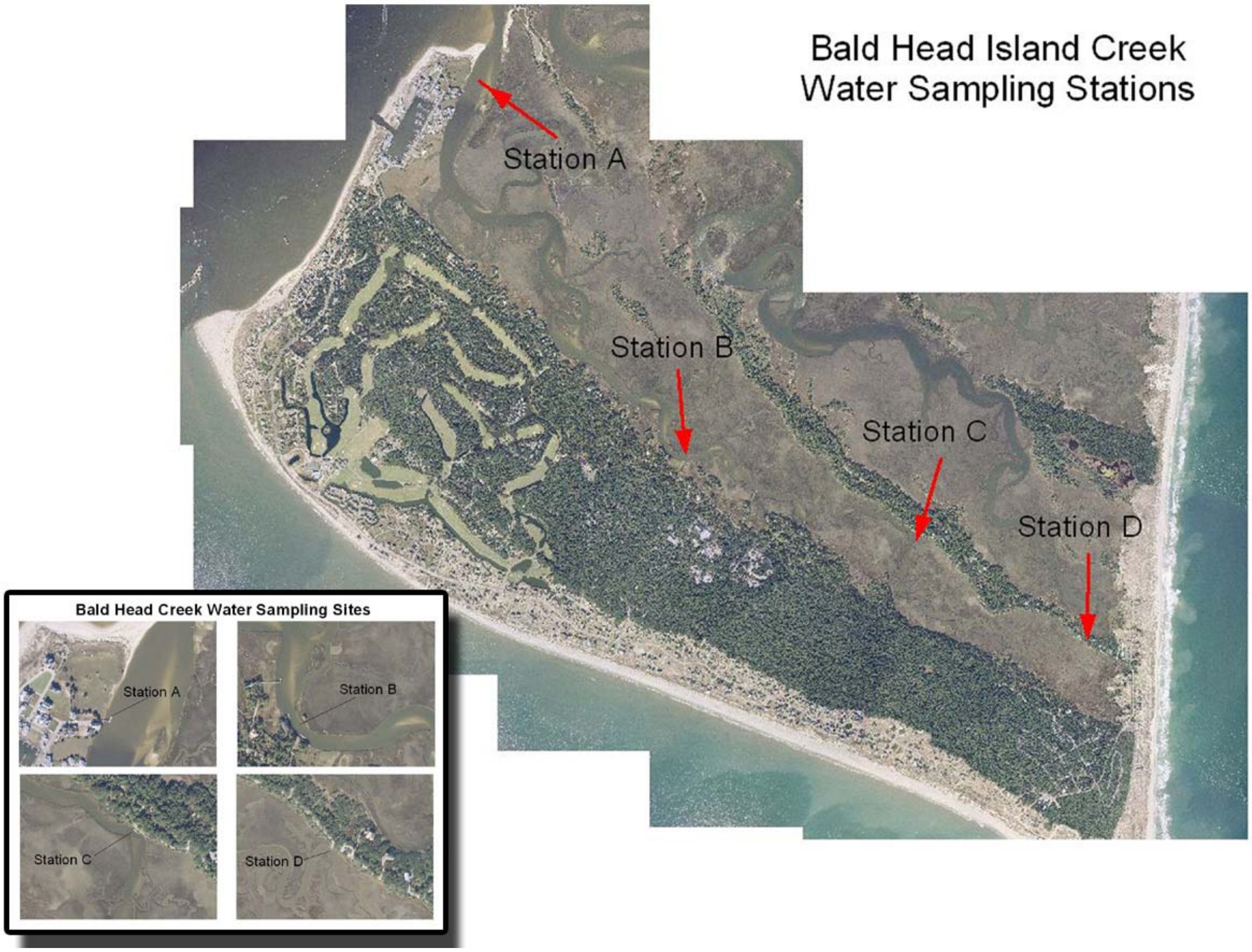
Bald Head Island Creek Water Sampling Stations

Figure 2. Geometric mean fecal coliform bacteria (FC) concentrations versus mean salinity at four Bald Head Creek sampling stations.

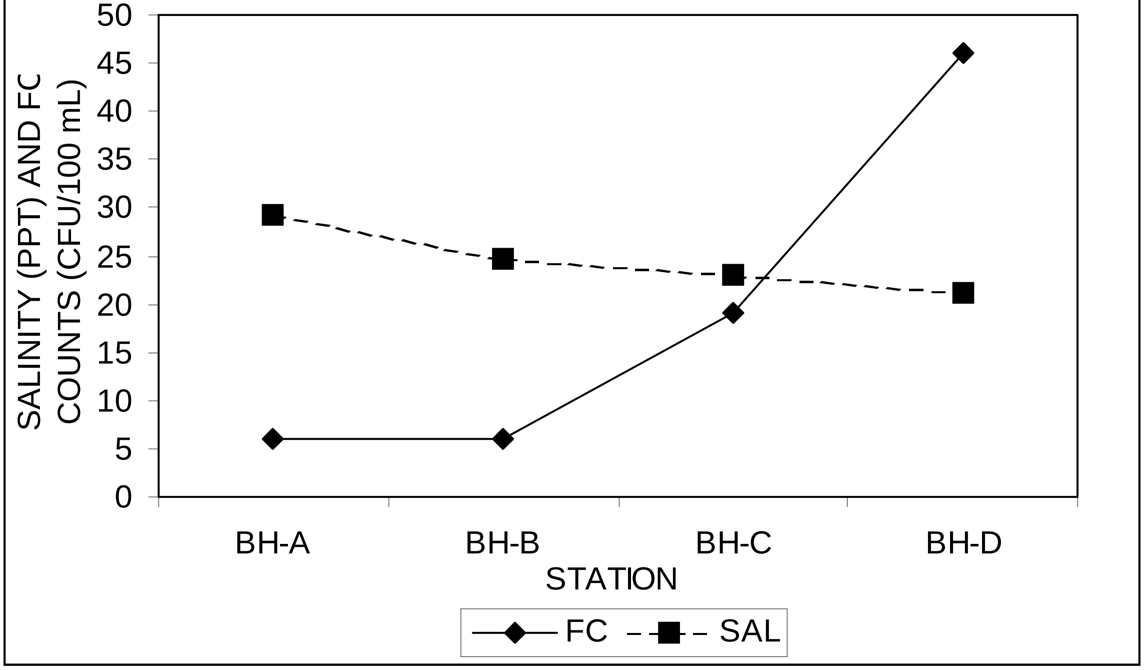

Figure 3. Mean nitrate and orthophosphate concentrations at four Bald Head Creek stations.