Eutrophication Assessment of Swashes

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Hypothesis

Storm water runoff has a significant effect on the degree of eutrophication in the swashes and surf zone along the Grand Strand Area, South Carolina. This effect is increasing with increasing development along the Grand Strand.

Eutrophication

- Eutrophication is a syndrome caused by nutrient loading, particularly of the elements, nitrogen and phosphorus. These nutrients can come from stormwater runoff containing:
  - Fertilizers
  - Feces (also contains coliform bacteria). Sources of feces include:
    - Humans
    - Pets
    - Livestock
    - Wildlife
- Nutrient loading can stimulate algal growth (as measured by chlorophyll).
- The resulting organic detritus can be decomposed by aerobic heterotrophic bacteria.
- Oxygen deficits can result (as measured by dissolved oxygen and percent saturations).

Parameters measured in this study.

SUMMARY OF EUTROPHICATION CRITERIA

Eutrophication is a widespread problem. Various government agencies in the United States have proposed several sets of criteria for diagnosing the degree of pollution.

Analytes	Estuary**	Rivers* (Ecoregion XIV)	South Carolina Lakes$
Phosphorus (ppm P)	0.1	0.0525	0.06
Nitrogen (ppm N)	1	0.87***	1.5
Chlorophyll a (ppb)	20	0.44	40
Turbidity (NTU)	NA	3.89	50

*in draft form: Ambient Water Quality Criteria Recommendations from US EPA's Office of Water. Ecoregion XIV, Level III Ecoregion 63.
***Nitrate + Nitrite criteria is 0.04 ppm N.

** in draft form from: National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries (Bricker et al. 1999) from NOAA. Hypoxia, DO concentration < 2 ppm.

$South Carolina: R.61-68 Water Classification and Standards approved 2001. Shown are the criteria for lakes in Piedmont and Southeastern Plains ecoregions.

Sampling Strategy

- A total of nine swashes (small tidal creeks) were sampled (some in duplicate).
  - Grab samples were collected in the swash during an ebbing tide
  - Samples were also taken in in the surf zone of the ocean.
    - 100 feet north of the mouth of the swash
    - 100 feet south of the mouth of swash

This procedure resulted in 15 sampling sites. Samples were collected by the 41 students in MSCI 305: Marine Chemistry in Spring 2004. Similar sampling was also conducted during 1994 to 2002 providing an opportunity to perform long-term trend analyses.

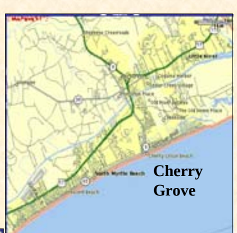
- Analytes tested included:
  - Eutrophication Benchmarks
    - Dissolved Oxygen and Percent Saturation of Dissolved Oxygen
    - Nitrate + Nitrite
    - Phosphate
    - Chlorophyll
  - Some others
    - Salinity (tracer of fresh water mass)

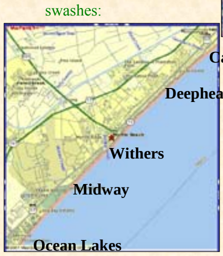
Sampling Sites

A number of sites were sampled along the total length of the Grand Strand. These included sites as far north as North Myrtle Beach, SC and as far south as Surfside Beach, SC. This broad range of sites produced a comprehensive picture of eutrophication along the Grand Strand. The sites included:

- Cherry Grove, North Myrtle Beach
- Cane Patch Swash, Myrtle Beach
- Deephead Swash , Myrtle Beach
- Withers Swash , Myrtle Beach
- Midway Swash , Myrtle Beach
- Ocean Lakes Swash , Myrtle Beach
- Dogwood Swash, Surfside Beach
- 13th Avenue S, Surfside Beach

Map views of the locations of the swashes:





Dogwood & 13th Ave. S., Surfside Beach

Sampling Dates

Due to the large number of samplers, water for different analytes was collected on different days. This allowed for proper collection and analysis of data. Those dates were:

- Dissolved Oxygen, Salinity, Temperature and Bacteria
  - February 4 and 5, 2004
- Nutrients and Chlorophyll
  - March 10 and 11, 2004
- Nitrate and Nitrite
  - April 7 and 8, 2004

Methods

A number of different methods were used to analyze the samples. These included:

- Dissolved Oxygen by Winkler Titration*
- Salinity by Knudsen Titration
- Temperature by Thermometer
- Phosphate and Nitrate + Nitrite by Beer's Law*
- Chlorophyll and Phaeopigement by Fluorometry*
- Total and E. Coliforms by Membrane Filtration using Hach™ m-Coli Blue media

*Parsons, T.R., Y. Maita, and C.M. Lalli. 1984. A Manual of Chemical and Biological Methods for Seawater Analysis. Pergamon Press, N.Y., 173 pp.

DATA

Parameter concentrations are presented as a function of location for the swashs, samples collected north of the swash and samples collected south of the swash. The means for the swash, north and south samples are presented along with one standard deviation. A single-factor analysis of variance (ANOVA) was performed to determine whether any significant differences existed among these means. A two-sample t test was also performed to determine if the north samples were significantly difference than the south samples.

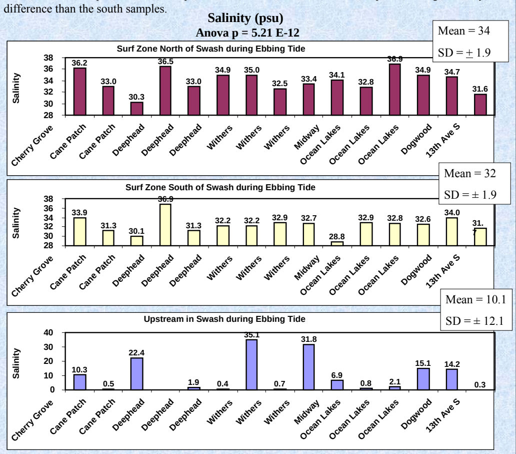


Figure 1: Figure 1 shows the results of the salinity analyses. An ANOVA (p= 5.21 x 10^{-12}) demonstrates that the salinity in the swash was lower than the surrounding ocean salinity indicating the presence of a significant amount of freshwater discharge. The few high values observed in the swash are probably the result of sample collection on a flooding tide. The salinity south of the swashes was significantly lower (p= 0.012) than the salinity north of the swashes suggesting that the longshore current carries swash water in a southerly direction. This has been observed for most of the sampling years.

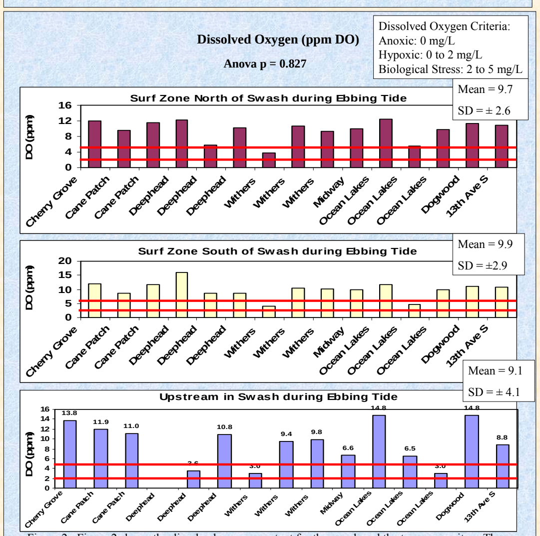


Figure 2: Figure 2 shows the dissolved oxygen content for the swash and the two ocean sites. The mean DO in the swash was higher than in the ocean, but this difference was not significant (p = 0.827). The higher DO's in some of the swashes are most likely the result of algal growth associated with eutrophication.

Certain swashes have supersaturated conditions suggesting the input of oxygen from an algal bloom. Some swashes are undersaturated, suggesting removal of oxygen. This removal may be from aerobic respiration from the decomposition of organic matter (possibly a previous algal bloom). There are corresponding highs and lows in the ocean sites south of the swash suggesting a southerly longshore current.

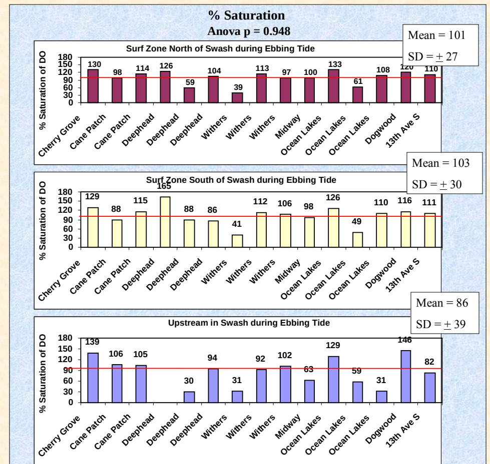


Figure 3: Figure 3 shows the percent saturation of oxygen for the swash and corresponding ocean sites. Six of the swash samples were supersaturated with oxygen (> 100%) and six were significantly undersaturated (< 100%). This large variability suggests large differences in loading of nutrients and oxygen-demanding substances among the swashes. Ocean samples from Withers, Deephead, and Ocean Lakes swashes were also significantly undersaturated suggested an influence from the adjacent DO undersaturated swashes.

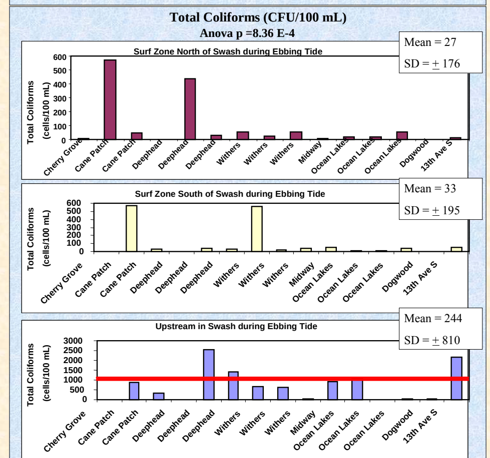


Figure 4: Figure 4 shows the values for total coliform bacteria in the swash and corresponding ocean. The swash shows significantly elevated levels of bacteria as compared to the ocean (p = 8.36 x 10^{-4}). No federal criteria swimming criteria exists for Total Coliforms. Total coliform concentrations in excess of 1200 CFU/100 mL are considered by the USGS (water.usgs.gov/owq/FieldManual/Chapter7.1/7.1.html). The state of California using a criteria of 1000 CFU/100 mL. Three of the swashes exceeded these criteria.

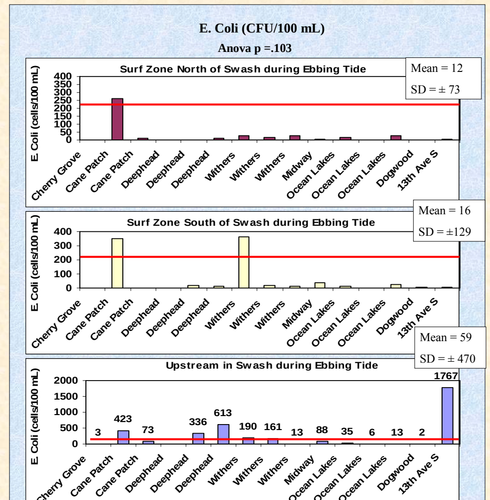


Figure 5: Figure 5 shows the values for E. coli in the swash and corresponding ocean sites. As in Figure 4, the bacteria levels are not higher in the swash as compared to the ocean (p = 0.103). Two of the ocean sites and four of the swash sites exceeded the US EPA's single sample freshwater swimming criteria of 235 CFU/100 mL. These limits correspond to approximately 8 gastrointestinal illnesses per 1000 swimmers. (Dufour, Alfred P. (1984). Health Effects Criteria for Fresh Recreational Waters. EPA-600/1-84-004. Office of Research and Development, USEPA, Washington, DC.)

on the Grand Strand of South Carolina

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Total Nitrogen (µM N)

Anova p =1.37 E-4

Total Nitrogen Criteria:
High: > 71 µmol/L
Medium: 7.1 to 71 µmol/L
Low: 0 to 7.1 µmol/L

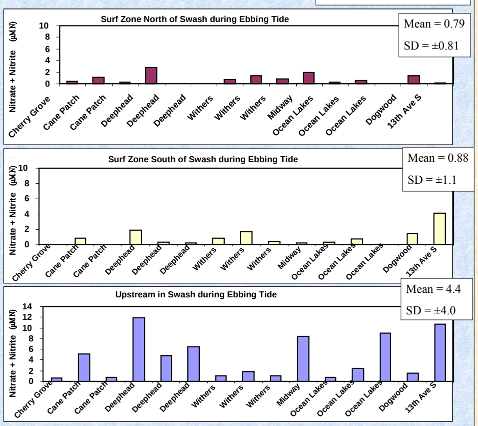


Figure 6: Figure 6 shows the nitrate + nitrite values for the swash and corresponding ocean sites. The nitrate + nitrite values for some of the swashes fell into the medium level of eutrophication status. Others fall into the low level of eutrophication status. Nitrate + Nitrite in the swashes was significantly higher than in the surf zone (p = 1.37E-4). The ocean sites south of the swash were slightly more contaminated with nitrogen than the ocean sites north of the swash, indicating a southerly flow of the longshore current.

Phosphate (µM P)

Anova p =.205

Total Phosphorus Criteria:
High: > 31 µmol/L
Medium: 3.1 to 31 µmol/L
Low: 0 to 3.1 µmol/L

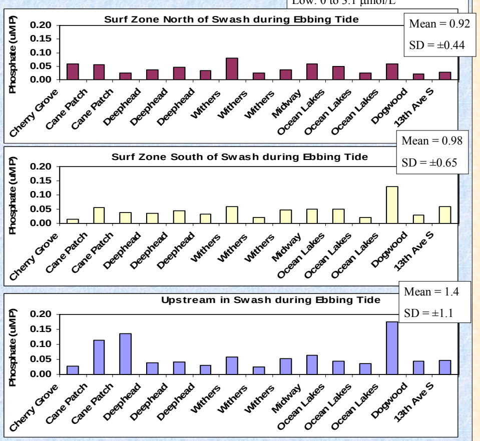


Figure 7: Figure 7 shows the phosphate values for the swashes and corresponding ocean sites. None of the swashes appear to exhibit phosphate concentrations suggestive of eutrophication although the concentration in the swash is not significantly higher than in the surf zone (p = 0.205). The ocean sites south of the swash were slightly more contaminated with phosphate than the ocean sites north of the swash, indicating a southerly flow of the longshore current.

Chlorophyll (mg/m³)

Anova p =0.917

Chlorophyll Criteria:
High: > 60 mg/L
Medium: 5 to 20 mg/L
Low: 0 to 5 mg/L

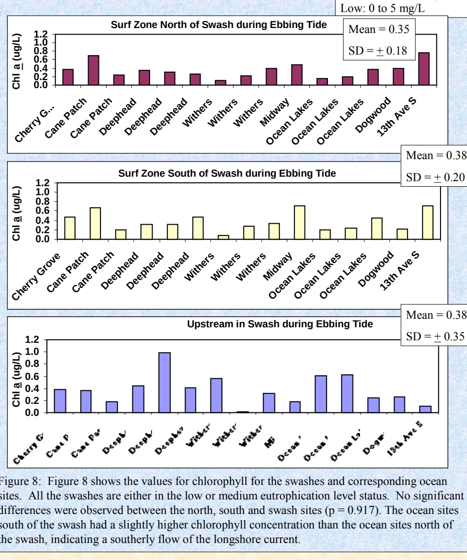


Figure 8: Figure 8 shows the values for chlorophyll for the swashes and corresponding ocean sites. All the swashes are either in the low or medium eutrophication level status. No significant differences were observed between the north, south and swash sites (p = 0.917). The ocean sites south of the swash had a slightly higher chlorophyll concentration than the ocean sites north of the swash, indicating a southerly flow of the longshore current.

Yearly Trends

Introduction to Trends Analysis

Data collected from 1992 to 2002 from the surf zone has been compiled to compute annual means. In the case of E. Coli, annual means are reported separately for swash, north and south in the surf zone. Error bars represent one standard deviation around the annual mean. Annual means that are significantly different have been identified via ANOVA. These data are used to assess long-term trends in surf zone quality. In general, no significant long-term increases in pollutants were observed.

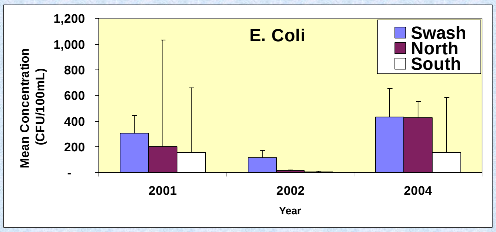


Figure 9: Figure 9 shows the average E. Coli values for 2001, 2002, and 2004. The concentrations were lowest in 2002 probably reflecting lack of rainfall during that year. No significant difference among the years was observed for the swash or north or south of the swash in the surf zone.

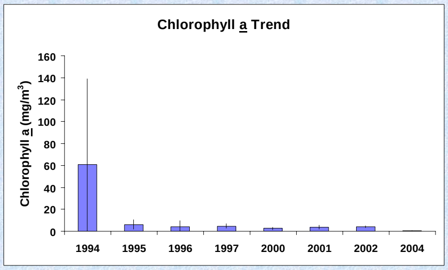


Figure 10: Figure 10 shows yearly chlorophyll a values between 1994 and 2004. An ANOVA test was performed (p = 2.12E-14) and shows that the chlorophyll a values over the years are significantly different. This is most likely due to the extremely high level of chlorophyll a in 1994. Another factor may also be the low level in 2004, which may be due to the samples being taken after a bloom.

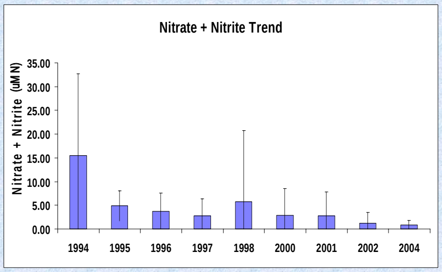


Figure 11: Figure 11 shows yearly nitrate + nitrite values between 1994 and 2004. An ANOVA test was performed (p = 0.186) and shows that the differences over the years are not significantly different. The minor fluctuations in the values may be due to differences in rainfall and sampling different stages of plankton blooms.

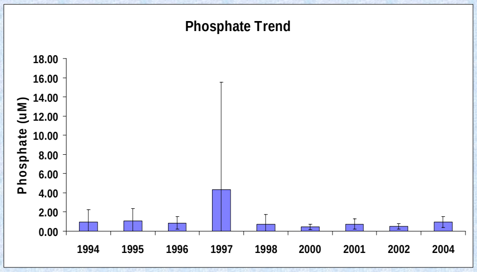


Figure 12: Figure 12 shows yearly phosphate values between 1994 and 2004. An ANOVA test was performed (p = 0.00542) and shows that the phosphate levels over the years are significantly different. It is most likely the high level of phosphate in 1997 that is causing the low p value. The differences may also be due to differences in fertilizing techniques over the years but as with the total nitrogen, may be due to differences in rainfall and sampling different stages of plankton blooms.

Conclusions

- The swashes show elevated levels of the following analytes suggesting influence of nonpoint runoff of sewage and/or fertilizers. Nonpoint runoff is the run-off from fields and the ground during rain events.
  - Chlorophyll
  - Nitrate + Nitrite
  - Phosphate
  - Bacteria
  - Dissolved Oxygen (showed levels of supersaturation)
- The ocean sites have low levels of:
  - Salinity (due to the influence of freshwater)
  - Nutrients (post bloom?)
  - Chlorophyll (post bloom?)

•The evidence for eutrophication includes:

–Chlorophyll (low levels of eutrophication)

–Nitrate + Nitrite (low levels of eutrophication)

–Phosphate (medium levels of eutrophication)

–Dissolved Oxygen (the supersaturated level of dissolved oxygen indicates an algal bloom.)

• The majority of the analytes indicated a southerly flow of the longshore current. This is important in predicting which area of the surf zone will be affected most by the outflow from of the swashes.

•There was evidence of bacterial contamination suggesting that at least some of the nutrient loading was associated with feces.

–Some sites exceeded the swimming standard of 126 CFU/100 mL for E. Coli AND the 200 CFU/100 mL standard for fecal coliforms. (These are US EPA swimming water criteria). These sites include:

–Deep Head Swash

–Withers Swash

–Cane Patch Swash

–Elevated levels were observed in the swash AND the surf zone at these sites.

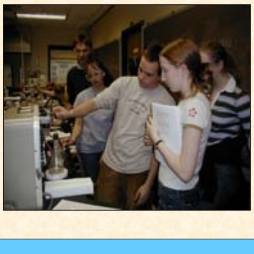
Students at Coastal Carolina University analyze dissolved oxygen content of the sites for their Marine Chemistry lab.

Acknowledgments

We thank the following groups of people for their help and contributions:

- Spring 2004 Marine Chemistry Class, Coastal Carolina University
- Marine Science Department, Coastal Carolina University
- Environmental Quality Lab, Coastal Carolina University

Students perform titrations for dissolved oxygen content on samples taken from the swash and north and south of the swash at their site in Myrtle Beach.



Andy Defobis, a student lab assistant, shows Marine Chemistry students how to use a salinometer to measure the salinity of their samples.