Ecological Assessment of Effects of Effluent from Reverse Osmosis (RO) Water Treatment Plants (WTP) - Albemarle Sound, NC

Rulifson, Roger; Woods, Terri; Kleber, Katharine; Smith, Jennifer

Institute for Coastal and Marine Resources, East Carolina University
Department of Geological Sciences, East Carolina University

Acknowledgments

- Groundwater Management Associates, especially Pete Moncla
- County of Camden for use of the Camden RO-WTP station as a model
- ECU Office of Diving and Water Safety
- Field and laboratory crews were mostly ECU graduate and undergraduate students: Brad Panneton, Cindy Anderson, Garry Wright, Walter Curtis Hodges, Jennifer Smith, Leigh Barnett, Amanda Martin, Kelly Register, Michael Chad Smith, Brandon Hendricks, Jeremy Brandsen, Jennifer Woodroffe, Tripp Amos, Robert Howard, David Parks, Michael Woods, Stephen Woods, Eric Rulifson, and Heather Rulifson.
- Jeremy Brandsen deserves special credit for the 3-D graphics and contour maps
- Dr. Roger Robbins provided assistance in macrobenthos identification
- Thanks also to Cindy Harper and Kay Evans in the Institute office
- Dr. Anthony Overton for SAS database construction and development of the SAS algorithms required to merge hourly weather data to hourly summaries of ADCP data.
- Mike Loeffler of the NCDMF provided the requested information about fish and invertebrate collections at sites near the study area.
Sources of Water in the Study Area

- High in silts and clays
- Blackwater swamps and streams
- Tannins and lignins difficult to remove
- Groundwater very plentiful but saltier close to the ocean
RO Treatment Plants in North Carolina

Online (MLPD) –
Production = 49.9
Discharge = 13.2

Proposed (MLPD) –
Production = 37.9
Discharge = 12.6
Status of RO Impact Assessment

At this time there are no NC state or federal criteria for assessing the environmental impact of discharge waters.

Other states where RO is important (FL, CA, TX) don’t appear to be much farther along with these assessments than NC.

Each locality is unique with respect to biota, water flow, water chemistry, and sediment.

Oligohaline (0.5-5 ppt) estuaries of NC have received little study to document water quality or abundance of benthic macroinvertebrates.

Effect of blackwater influx must be considered.

No studies or models of cumulative effects of additional plants exist.
Study Objectives

1) Document existing environmental conditions at proposed discharge sites

2) Determine existing conditions at working RO-WTP at Camden

3) Document existing food chains at proposed sites and Camden site

4) Document seasonal patterns of change

5) Assess potential for Whole Effluent Toxicity to biota

6) Use results of Camden study to predict possible changes at proposed sites
Whole Effluent Toxicity

-Freshwater aquatic organisms may be adversely affected by effluents containing abnormal ratios & high concentrations of the major ions.

-In some cases the TDS alone causes the toxicity, or combinations of ions are responsible.

  high TDS (salinity close to 50% seawater)
  high Ca$^{2+}$ (especially Ca to Na ratio of 15:1)

Surface Water Classification (SB=primary recreation), NC DMF considers the areas fish spawning habitat.
Nearest beach Seine (▲) and Trawl (●) sites used by NCDMF to assess finfish abundance are several miles from any of the study sites.
Field and Laboratory Methods
Camden Water Sampling Locations

Bi-weekly (July 05 - June 06):
• Water Samples (Surf/bott)
  - Camden (13)
  - Control (1)
  - Pasquotank (2)
  - Currituck (2)
  - In-plant dschrg (1)
• YSI profiles

Monthly (at least July-Dec. 2005):
• SAV
• Benthos
• Sediments
• Plankton
• Fish Trawl
• Fish gillnet

Irregularly:
• Water
  - Osprey
  - Dock
  - Marina
  - P1-P4
To assess net water movement and long-term trends in current direction and speed we deployed:

**RD Instruments Acoustic Doppler Current Profilers (ADCP)**

Deployment and retrieval varied depending on availability from other locations, weather conditions, and availability of boats/ personnel
Periodic Water Quality Monitoring was conducted with Hydrolabs – Time Series

- Water temperature
- Dissolved oxygen
- Conductivity
- Salinity
- pH
- Turbidity
- Chlorophyll a

Deployed at shallow and deep locations
Recorded every 30 minutes

Model DS5X with luminescent DO probe
One set of surface and bottom water samples from one date
Biweekly Vertical Water Profiles

- Surface to bottom every 0.5 m
- Water temperature
- Conductivity
- Salinity
- Dissolved oxygen
- % saturation
Macrobenthic Organisms

- Ponar grab, 9x9 cm footprint
- Once per month at each station
- Sieved at 500 microns
- Identified to species group
- Presence/Absence
- Relative abundance
Clay and sand with rare SAV

Sandy

Vegetative debris
Submerged Aquatic Vegetation

- Concurrent with macrobenthos sampling
- Additional side-scan sonar techniques
- Samples identified, percent dominance by weight
Pelagic Organisms

- **Plankton**
  - Paired plankton tows of 1 minute

- **Nekton**
  - Two-minute trawl (NCDMF standard)
  - Experimental gillnets
    - (25-foot panels of 1”, 2”, 3”, 4”, and 5” stretch)
    - Overnight sets, 2 nets per station
Collection of Sediment Cores

Top 5 cm of each core was analyzed for grain size by pipette/sieve and for organic content by loss on ignition.
### Laboratory analysis of water samples

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Analytical method</th>
</tr>
</thead>
<tbody>
<tr>
<td>ph &amp; alkalinity</td>
<td>pH meter &amp; titrator</td>
</tr>
<tr>
<td>cations</td>
<td>ICP-OES</td>
</tr>
<tr>
<td>Cl(^-) &amp; SO(_4^{2-})</td>
<td>Ion chromatograph</td>
</tr>
<tr>
<td>nutrients</td>
<td>spectrophotometer</td>
</tr>
</tbody>
</table>

- Ca\(^{2+}\)  
- Mg\(^{2+}\)  
- Na\(^+\)  
- K\(^+\)  
- HCO\(_3^{-}\)  
- Cl\(^-\)  
- SO\(_4^{2-}\)  
- NO\(_3^{-}\) + NO\(_2^{-}\)  
- NH\(_4^{+}\)  
- PO\(_4^{3-}\)
Conditions at Camden RO-WTP Site
Camden RO-WTP was used as an operating model to predict possible influence of RO discharge at proposed sites.
### RO Plant Specifications

<table>
<thead>
<tr>
<th>Plant</th>
<th>Effluent Discharge (gal/day)</th>
<th>Freshwater Produced (gal/day)</th>
<th>Discharge Depth (m)</th>
<th>Distance from shore (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camden</td>
<td>300,000</td>
<td>600,000</td>
<td>2</td>
<td>250</td>
</tr>
<tr>
<td>Pasquotank</td>
<td>1,670,000</td>
<td>5,000,000</td>
<td>1 or 2</td>
<td>&lt;650</td>
</tr>
<tr>
<td>Currituck</td>
<td>1,670,000</td>
<td>5,000,000</td>
<td>1 or 2</td>
<td>280 or 550</td>
</tr>
</tbody>
</table>
Raw water feed to the ROWTP comes from 2, 600-ft wells in the Castle Hayne and 2, 100-ft wells in the Yorktown.

Concentration of major ions is in (mg/L).
Average daily discharge of the Camden Plant did not vary significantly over the course of the study.
RESULTS
Flow Units = m/hr;

Bottom velocities were generally slower than those at the surface.

Averaged results from ADCP profilers
Hydrolab-Continuous Water-Quality Monitoring
Camden RO-WTP and 7-ft contour at
Pasquotank & Currituck

--Shallow and deep locations exhibited similar
temperature and conductivity patterns for
summer and fall. Conductivities increased in fall

--Ambient dissolved oxygen remained above 4 mg/L
with exception of a few isolated day-long events

--Chlorophyll a values (late summer/early fall =
10-15 ug/L; up to 100 ug/L in November at
shallow location at Camden RO-WTP
No SAV beds were located within the targeted areas at either the proposed Pasquotank County discharge site in Albemarle Sound, or in Chantilly Bay at the Camden RO-WTP site or the control site.

Visual surveys were unproductive because of the darkly-stained waters in Chantilly Bay, and because of the milky-colored waters of the proposed Pasquotank County discharge site in Albemarle Sound. Therefore, sidescan sonar surveys were employed.
SAVs – North River @ Currituck
SAVs – Only found at Currituck (4-ft)

- Southern Naiad 2.9
- Fish/Pond Weed 14.4
- Common Milfoil <0.1
- Eelgrass 5.3
- Shoal Grass 77.4
Sediment cores from August, 2005
Water Chemistry
Geographic Variations In Water Chemistry
<table>
<thead>
<tr>
<th>Sample type and locations</th>
<th>ppt (‰)</th>
<th>% of seawater salinity</th>
<th>Outliers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currituck Co. Discharge site</td>
<td>2-8.5</td>
<td>5-24</td>
<td></td>
</tr>
<tr>
<td>Castle Hayne groundwater</td>
<td>8.3</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td>Yorktown groundwater</td>
<td>0.9</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Camden RO-WTP Discharge</td>
<td>10.2-15.2</td>
<td>29.2 - 43.5</td>
<td>4.9 (7/07/05)</td>
</tr>
<tr>
<td>Osprey control –Hospital Point</td>
<td>0.7-4.0</td>
<td>2.1-11.4</td>
<td></td>
</tr>
<tr>
<td>Control – Chantilly Bay</td>
<td>0.8-5.0</td>
<td>2.3-14.3</td>
<td></td>
</tr>
<tr>
<td>RO-WTP surface sites</td>
<td>0.8-5.8</td>
<td>2.3-16.5</td>
<td></td>
</tr>
<tr>
<td>S1 B, N1B, W1B, E1B</td>
<td>0.8-5.9</td>
<td>2.4-16.9</td>
<td></td>
</tr>
<tr>
<td>S2B, N2B, W2B, E2B</td>
<td>0.8-6.0</td>
<td>2.4-17.2</td>
<td></td>
</tr>
<tr>
<td>S3B, N3B, W3B, E3B</td>
<td>0.8-5.6</td>
<td>2.4-16.0</td>
<td></td>
</tr>
<tr>
<td>Dock</td>
<td>0.8</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Marina</td>
<td>2.2</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>P transect sites</td>
<td>0.9-1.2</td>
<td>2.7-3.4</td>
<td></td>
</tr>
</tbody>
</table>

**Pasquotank Site ppt, % seawater and outliers**

1.9-6.1, 5.5-17 (11.0, 31.6)
Average Cations at each site

\[ \text{Na}^+ = 4694 \text{ discharge} \]

Variations between Surface sites at Camden RO-WTP did not often exceed sampling variation or analytical uncertainty.
Cl\textsuperscript{-} = 5463 discharge

Average Anions at each site

Variations between Surface sites at Camden RO-WTP often did not exceed sampling variation or analytical uncertainty.
**pH** showed less variation than other constituents at all sites, especially for bottom sites around Camden diffuser. Significantly higher at Currituck & Pasquotank than at any of the upstream locations.

**Alkalinity** showed significantly more variation in bottom sites than other ions at Camden. Higher at Currituck and Pasquotank sites than the Camden surface sites, but typically lower than all but the Camden bottom sites closest to the Diffuser.
Temporal Variations In Water Chemistry
Temporal variations in chemistry of in-plant discharge from Camden RO-WTP
Changes in discharge chemistry do not correspond to variations at sites near the Camden RO-WTP.
Seasonal variation in Na⁺
S1 site sometimes shows different pattern suggesting proximity of plume
With the exception of S1B, temporal variation in alkalinity was generally a muted reflection of patterns observed for conservative ions.
Temporal variation in alkalinity at “S” sites was quite different from that at the other Camden RO-WTP sites, such as “W”.

**S1 (490)**

**W1**

**S2**

**W2**

**S3**

**W3**
pH averaged 7.21-7.34 for Camden sites, but was much higher at Currituck (7.92) and Pasquotank (7.81). These are close to the in-plant discharge average of 7.85.
Values for in-plant discharge are 5.82 for NH₄ and 0.007 for NO₃ + NO₂
Variations in plume orientation
Conductivity values measured by YSI (uS) suggest plume extends up at least to within 1.5m of surface.
A preliminary statistical analysis of correlations between Camden water chemistries and local wind and temperature conditions was run using Minitab. A moderate correlation between plume position around the diffuser (indicated by Na concentration) and wind speed was observed, suggesting that weather conditions influence plume position.
Na / Cl ratio quite similar for groundwaters and surface waters
-HCO3 / Cl ratio significantly higher for groundwaters than surface waters.
-However, waters around the diffuser don’t show the same elevated ratio, except for a few bottom samples.
Potential to precipitate minerals?

- No samples collected were supersaturated with anhydrite (CaSO₄) or gypsum (CaSO₄ ⋅ 2H₂O).
- At Camden only in-plant discharge, groundwaters, and S1B were sufficiently supersaturated to have any potential to precipitate carbonates.
- But what about mixtures of discharge and the saltiest ambient water at Currituck?

Calculations with PHREEQCI indicated even a mixture containing only 10% discharge water will be supersaturated with calcite. However, such samples should not occur more than 100m from diffuser and saturated water should soon mix with unsaturated masses.
### Presence and Absence of Macroinvertebrate Taxa from July-December, 2005

<table>
<thead>
<tr>
<th></th>
<th>CHANTILLY BAY RO-WTP</th>
<th>PASQ</th>
<th>CURR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polychaetes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Marenzellaria virdis</em></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hobsonia florida</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Polydora ligni</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Drilonereis longa</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Family: Syllid</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nemertean fragment</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Leptocheirus plumulosus</em></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Monoculodes edwardsi</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Parahaustorius sp</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Gammaridae</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corophium sp.</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Cyanthura polita</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Chirididotea alymra</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Elotea montosa</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mysidopid almyra</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Rangia cuneata (&gt;1cm)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Rangia cuneata (&lt;1cm)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Mytilopsis leucophaeta</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chironomid larvae</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Trichoptera larvae</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Rhithropanopeus harrisii</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Callinectes sapidus</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total number of taxa</strong></td>
<td><strong>19</strong></td>
<td><strong>11</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

### Polychaetes
- Dominated by polychaetes & Amphipods
- *dominant species

Increased # of Taxa present at ROWTP may be due to greater sampling density (i.e.: 13 samples vs. 1 @ Control & 2 each @ Pasquotank and Currituck)
Densities (individuals /m²) of the polychaete, *Marenzellaria virdis*, at CamdenRO-WTP study site from July-December, 2005.

Polychaete worms dominant throughout sampling period.

* * indicates lost data.*

*M. Virdis* was rare at DIF & S1, where sediments are rich in organics and plume was frequently located. Also showed significant drop off in abundance after July, 2005. The same pattern was not observed for other species.

*H. Florida* (another Polychaete worm) didn’t show the same aversion for DIF & S1.

*L. Plumulosus* dominated amphipods and was fairly evenly distributed throughout sampling period.

<table>
<thead>
<tr>
<th>Month</th>
<th>W</th>
<th>N</th>
<th>E</th>
<th>*</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>230</td>
<td>517</td>
<td>306</td>
<td>421</td>
<td>0</td>
</tr>
<tr>
<td>October</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>November</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>September</td>
<td>0</td>
<td>16</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>December</td>
<td>0</td>
<td>7</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Numbers probably somewhat low because tows were done during the daytime. Distinct seasonality and highest average densities in July, 2005 and spring, 2006.

32 species-all sites-trawl & gill net.

~Equal diversity at all sites

-Several species found only at Pasquotank, Currituck (more marine-associated species) or only in Chantilly Bay (more fresh-water associated species)

-Atlantic Menhaden most abundant at all 4 sites followed by spot, white perch, Atlantic croaker, striped bass & bay anchovy

<table>
<thead>
<tr>
<th>Species</th>
<th>Camden ROWTP</th>
<th>Control</th>
<th>CURR</th>
<th>PASQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striped mullet</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Atlantic needlefish</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ladyfish</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Yellow perch</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Chain pickerel</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Bay anchovy</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Spotted seatrout</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weakfish (grey trout)</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golden shiner</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Bowfin</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Bluefish</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Black drum</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alewife</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Brown shrimp</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Summer flounder</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>American shad</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>White bass</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Hickory shad</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Common carp</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Atlantic sturgeon</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Number of Species</td>
<td>18</td>
<td>20</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Same as Control</td>
<td>17</td>
<td>-</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Same as Camden</td>
<td>-</td>
<td>17</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>

Found at all locations: Atlantic menhaden, Blue crab, Silver perch, Hogchoker, Spot, White perch, Atlantic croaker, Striped bass, Southern flounder, Gizzard shad, Longnose gar, and White catfish.
Number of fish *species* & blue crab for July, 2005 – June, 2006 (trawl & gill net)

Appears to be a seasonal component to # of species caught with highest abundances in September and October and lowest in December and February.
The majority of the increases in the number of individuals present at all sites was juvenile Atlantic menhaden (*B. tyranus*).
## Taxa of macroplankton for July through December, 2005

<table>
<thead>
<tr>
<th>Zooplankton</th>
<th>RO-WTP</th>
<th>Control</th>
<th>PASQ</th>
<th>CURR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphipod</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Arthropod</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Blue crab zoea</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Blue crab megalopae</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Bougainvillea superciliaris</em></td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Insect larvae</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chironomidae (Family Diptera)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ctenophores</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Shrimp</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Fish larvae</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Fish eggs</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Polychaete</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total number of groups</strong></td>
<td><strong>5</strong></td>
<td><strong>7</strong></td>
<td><strong>7</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

-Average plankton densities were low at all sites and only 12 species groups occurred.
-Fish eggs found only at proposed sites and only in May, 2006.
-Larval fish found only at Control (May) and Currituck (Sept., May, June).
-Pasq&Curr: 3 common groups: amphipods, blue crab zoea & unspecified shrimp species.
-Camden&Control: insect larvae sometimes most common, or else blue crab zoea.
CONCLUSIONS
General Conclusions

▪ The Camden RO-WTP site and the proposed sites for the Currituck and Pasquotank County RO-WTP discharges are similar to other locations in this portion of North Carolina for water quality, and distribution and relative abundance of benthic and pelagic organisms.

▪ Sediment at all study sites was primarily sand-sized and averaged ~ 2% organic matter.

▪ As expected, the ambient water at the proposed Currituck and Pasquotank County discharge sites in Albemarle Sound is significantly saltier (about 1.5-4 times as salty) than the ambient river water at the Camden site.

▪ Ambient waters had lower salinity during summer and increased in salinity during the fall.

▪ Except within the sampling grid at the Camden RO-WTP site, the water column at all sampling sites was relatively well-mixed.

▪ The proposed sites are in exposed and high energy locations, which will be important in mixing RO-WTP discharge concentrate with ambient waters.
Camden RO-WTP Site

- For all ions at the Camden RO-WTP, concentrations were much more variable at the bottom sites around the diffuser than at surface sites, and generally showed decreasing concentrations away from the diffuser in all directions. Surface waters were not noticeably affected and showed less variable chemistry than bottom waters.

- The plume emanating from the Camden RO-WTP diffuser was easily detectable by major-element analysis, but not readily apparent to common hand-held equipment (YSI water quality meter) or to stationary monitoring equipment (i.e., Hydrolab). The plume shifts its position frequently, presumably with prevailing wind and current conditions.

- The discharge was not detectable at the Control site, nor in a linear transect away from the diffuser (“P” sites) into the Pasquotank River. The discharge signal was not detectable more than about 50 meters from the diffuser. There was no evidence that the embayment containing the Camden RO-WTP is accumulating the discharge Stream.

- The relative abundances and distributions of benthic organisms at the Camden RO-WTP did not indicate that there was influence from the discharge plume, with the possible exception of the sampling grid containing the diffuser and possibly one adjacent grid (S1).
Water Quality Issues of Particular Concern

- Only one sample, an in-plant discharge (44% of seawater salinity), was close to being half the salinity of seawater – a value that was shown by laboratory study, either directly or indirectly, to be responsible for toxicity due to osmotic stress.

- In all of the surface waters analyzed, including areas immediately surrounding the diffuser pipe at the Camden RO-WTP, Ca2+ to Na+ ratios ranged from 0.026-0.08. These ratios are much less than the value of 15:1 observed to cause high mortality rates among test organisms. Of the major-element ratios, only HCO3-/Cl- was significantly higher than ambient ratios and this was only for a few bottom samples nearest the diffuser.

- Significantly higher ammonium concentrations within 15 meters of the diffuser at the Camden RO-WTP suggest the possibility of increased photosynthetic activity and perhaps algal blooms. No such effect was observed during the study period, however, the naturally dark color of the river water results in visibilities of less than 0.5 meters suggesting that minimal light penetration may limit photosynthesis. High ammonium levels could be a more significant problem in the well-lit estuarine waters at the proposed discharge sites.

- Calcium carbonate is the only mineral likely to achieve saturation in any receiving water influenced by discharged concentrate, but precipitated phases should quickly redissolve in shifting water masses.
Biota

• At all sites dissolved oxygen concentrations were consistently good for fish, benthic, and pelagic organism health.
• At both of the proposed sites, six taxa of benthic invertebrates were present in abundances similar to that of the Camden RO-WTP and Control site. No unique or rare species were present.
• Fish diversity at the Control and Camden RO-WTP sites was similar to that observed at the Currituck and Pasquotank County sites, and was similar to that reported by NC Division of Marine Fisheries sampling surveys from 1972-2005.
• Fish larvae were collected in plankton samples at the Currituck County site only in September 2005 and May and June 2006. Fish eggs were present in plankton samples only in May 2006. No eggs or larvae were collected in plankton samples from the Pasquotank County site.
• Submerged aquatic vegetation (SAV) was only present on the sandy substrate shoreward of the 4-foot contour at Currituck.