Outfall Monitoring:
Benthic Infauna

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Stations sampled in 2010 were the “even-year” set of stations.

NF12 and NF 17 are sampled in triplicate each year.

FF10 and FF13 are also sampled in triplicate in even years.

Single samples are taken at all other stations.
Overview of trends at nearfield stations

- Baseline levels were established after sampling from 1992-2000, prior to relocation of the outfall discharge
- These values reflect the entire station set
Mean abundance was lower than in 2008, but comparable to 2006.

Mean abundances have been lower than baseline mean since 2004.

Mean species per sample was slightly higher than baseline, but not the highest - or lowest - seen for this station subset.
The Shannon index was much higher than baseline, and similar to but higher than 2004. The value (4.23) exceeded the threshold value of 4.14.

Mean alpha declined slightly, to 14.47, but was higher than baseline.
Evenness was the highest calculated for this station subset. The value of 0.70 was an exceedance of the MWRA threshold value (0.68).
2010 Threshold Exceedances

- MWRA ran Contingency Plan threshold tests for nearfield infaunal diversity and the abundance of opportunists.

- Two of the diversity parameters calculated, Shannon-Wiener H’ and Pielou’s J’, were slightly higher than their threshold ranges. Those results were a “Caution” level threshold exceedance and required regulatory and public notification.

- Other parameters were well within threshold ranges

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low threshold</th>
<th>High Threshold</th>
<th>2010</th>
<th>Exceedance?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total species</td>
<td>48.4</td>
<td>82</td>
<td>65.1</td>
<td>No</td>
</tr>
<tr>
<td>Log-series alpha</td>
<td>9.99</td>
<td>16.47</td>
<td>14.37</td>
<td>No</td>
</tr>
<tr>
<td>Shannon-Wiener H’</td>
<td>3.37</td>
<td>4.14</td>
<td>4.23</td>
<td>Yes, Caution</td>
</tr>
<tr>
<td>Pielou’s J’</td>
<td>0.58</td>
<td>0.68</td>
<td>0.70</td>
<td>Yes, Caution</td>
</tr>
<tr>
<td>Percent Opportunists</td>
<td></td>
<td>10%</td>
<td>0.60%</td>
<td>No</td>
</tr>
</tbody>
</table>
“Caution” levels led to questions

- What caused the exceedances: did abundances of any species exhibit a notable change?

- Did the exceedance in diversity and evenness reflect a regional or localized trend? Did all stations exceed the threshold values?

- Where elevated, was this against the regional baseline or against historical levels at individual stations?

- Did any station exhibit signs of recent disturbance (as evaluated by Gallagher’s non-dimensional diversity technique)?
Overall species composition in the nearfield has not changed recently

<table>
<thead>
<tr>
<th>Top Numerical Dominants in 21 Nearfield Samples 2010</th>
<th>Overall NF Dominants since 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prionospio steenstrupi</td>
<td>Prionospio steenstrupi</td>
</tr>
<tr>
<td>Mediomastus californiensis</td>
<td>Mediomastus californiensis</td>
</tr>
<tr>
<td>Levinsenia gracilis</td>
<td>Spio limicola</td>
</tr>
<tr>
<td>Tharyx acutus</td>
<td>Aricidea catherinae</td>
</tr>
<tr>
<td>Spio limicola</td>
<td>Tharyx acutus</td>
</tr>
<tr>
<td>Aricidea catherinae</td>
<td>Ascidiacea</td>
</tr>
<tr>
<td>Ninoe nigripes</td>
<td>Ninoe nigripes</td>
</tr>
</tbody>
</table>
The abundance of *Prionospio steenstrupi* at nearfield stations has crashed in recent years ~ a natural fluctuation

All NF stations (black), even-year subset (blue), odd-year subset (red).
Robert May observed that the distribution of species among the individuals in a marine benthic sample (i.e., Sanders’ deep-sea samples) follows a log-series curve. A severe departure from this distribution indicates a disturbance of some sort.

Gallagher’s procedure:
1. Calculate Sanders-Hurlbert rarefaction curves for each sample.
2. Calculate the corresponding log-series curve for each sample.
3. Evaluate the difference between the two curves.
4. Plot as non-dimensional diversity curves. Samples falling above or below set levels are considered “disturbed” in some way.
Non-dimensional diversity curves for 2010 samples

2 samples fall below the 0.75 level: FF13-2 & FF13-3

2 samples fall right on the 0.75 level: FF13-1
Did the exceedance in diversity and evenness reflect a regional or localized trend? Did all stations exceed the threshold values?

- 16 of 21 replicates – and 10 of 13 stations – had evenness higher than 0.70 and Shannon diversity of 4.14 or higher.

- NF07, NF17, and FF13 were the three exceptions.

- FF10, FF13 and F08 were evaluated in more detail.
Shannon diversity (and evenness) have shown a cyclic trend.

H′ was 4.41 in 1992, as it was in 2010, and even higher in 1993, 1995, 1996, 1997, and 2004.

J′ was similarly elevated in those years.
Neither Shannon diversity nor evenness were elevated over the “high threshold” levels at this station in 2010.
This analysis shows that 75% of the samples from FF13 could be considered “disturbed” in some way – but the most recent samples (#46 - 48) did not exhibit the most severe departure from a log series distribution.
Red lines indicate clusters with high similarity, as determined by SIMPER analysis; these clusters are usually the three replicates in a sampling year.

Bray-Curtis similarity analysis of replicates from FF13 suggests that:

- early years 1992-1995 differ from all other sampling years
- recent years (2006-2010) are most similar to predischarge years 1998-1999

2010 is similar to the last two sets of samples in 2006 and 2008; this pattern is typical of all stations analyzed.
PCA analysis of FF 13
Trends at NF 08

Shannon diversity and evenness are plotted along with abundances of *Prionospio steenstrupi*.

In 2010, both $H'$ and $J'$ were higher than the regional “high threshold” levels.

These plots suggest that when *P. steenstrupi* is abundant, diversity and evenness are depressed.

When *P. steenstrupi* populations crashed, both parameters were elevated.
Curves for early years show a greater “disturbance” than in later years.
PCA-H analysis of NF 08
What caused the exceedances: did abundances of any species exhibit a notable change?

- Population fluctuations of the polychaete *Prionospio steenstrupi* most likely resulted in the elevated evenness and Shannon diversity at several stations in 2010.

Did the exceedance in diversity and evenness reflect a regional or localized trend?

- Many of the stations sampled in 2010 exhibited this trend, again because *P. steenstrupi* has been dominant at several stations and lower abundances of that species resulted in higher evenness and higher Shannon diversity.
Where elevated, was this against the regional baseline or against historical levels at individual stations?

- Against the baseline, which is calculated on a pooling of several stations over time. When examined individually, samples from many stations sometimes exceeded the thresholds in earlier years.

- Did any station exhibit signs of recent disturbance (as evaluated by Gallagher’s non-dimensional diversity technique)?

  - Only two stations sampled in 2010 evidenced such disturbance, but samples taken in earlier years at several stations exhibited even more severe departures from “normal.”
Farfield Stations
Mean Benthic Parameters at Farfield Stations

No. of Species

Mean no. of species declined, driven by changes at FF04 in Stellwagen Basin. Some species were either absent or occurred in lower numbers.

Abundance (Density)

Mean density per sample declined, driven by large drops at FF04 and FF05. Fluctuations in the population of *P. steenstrupi* was the major change.
Diversity (Shannon’s $H'$)
Mean $H'$ was lower than in 2008, but above baseline. A decline was seen at FF04, the other stations were essentially the same as in 2008.

Diversity (Fisher’s $\alpha$)
Mean $\alpha$ was lower than in 2008, but above baseline. As for $H'$, a decline was seen at FF04, but the other stations were essentially the same as in 2008.

Evenness (Pielou’s $J'$)
Mean $J'$ was the same in 2010 as in 2008 (0.71).
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- MWRA