

PLEASANT BAY WATER QUALITY: ANALYSIS OF 2000-2014 TRENDS

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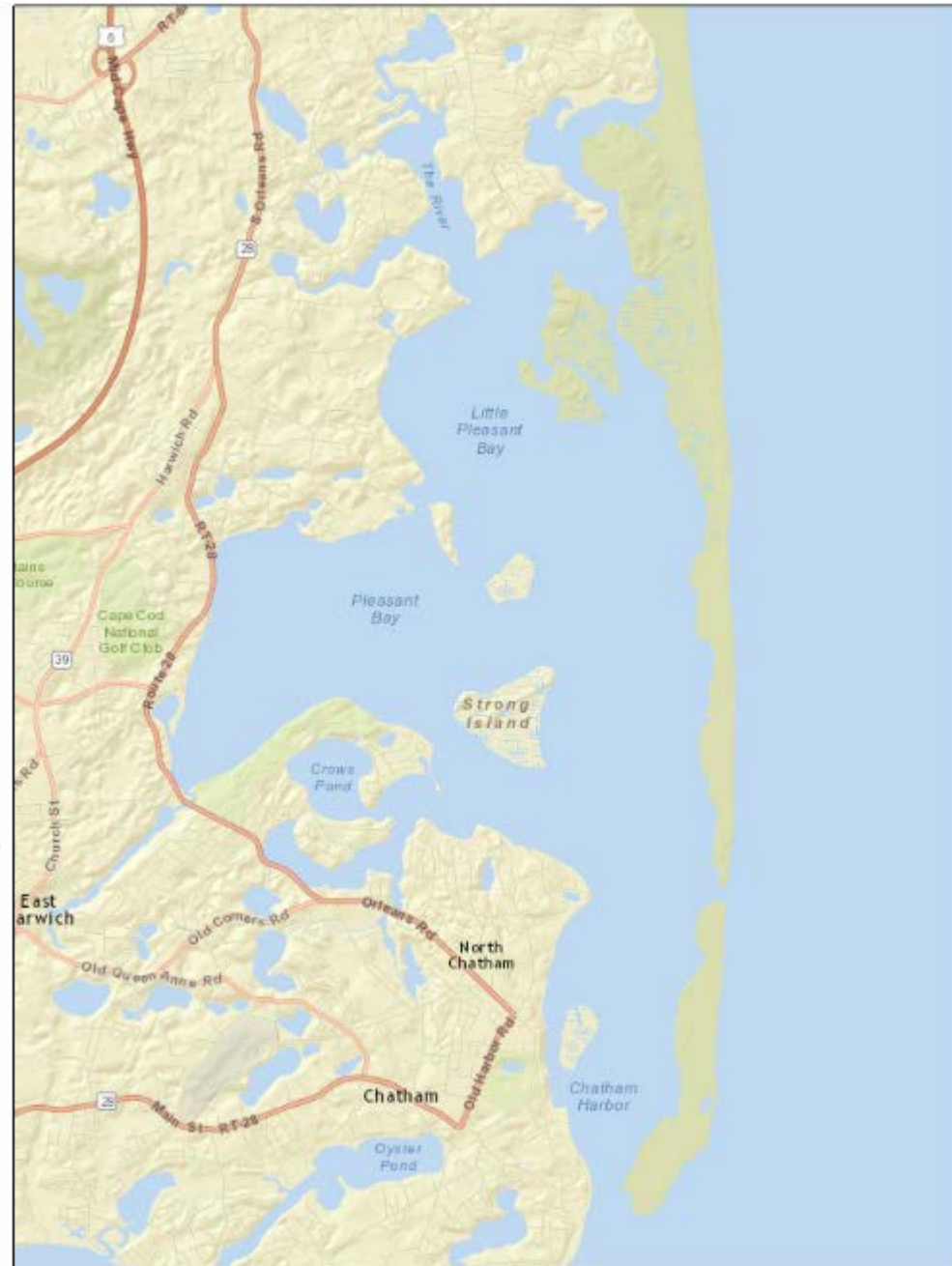
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Agenda

- Background
- Study Objectives and Methods
- Station-Specific Trend Results
- Bay-Wide Results Trends
- Questions

Pleasant Bay

- Largest estuarine system on Cape Cod (~7,000 acres)
 - Main basin
 - Sub-embayments
 - Salt marshes
 - Tidal flats
- Freshwater inflow from streams and direct groundwater discharge
- Tidal exchange from two breaks in barrier beach



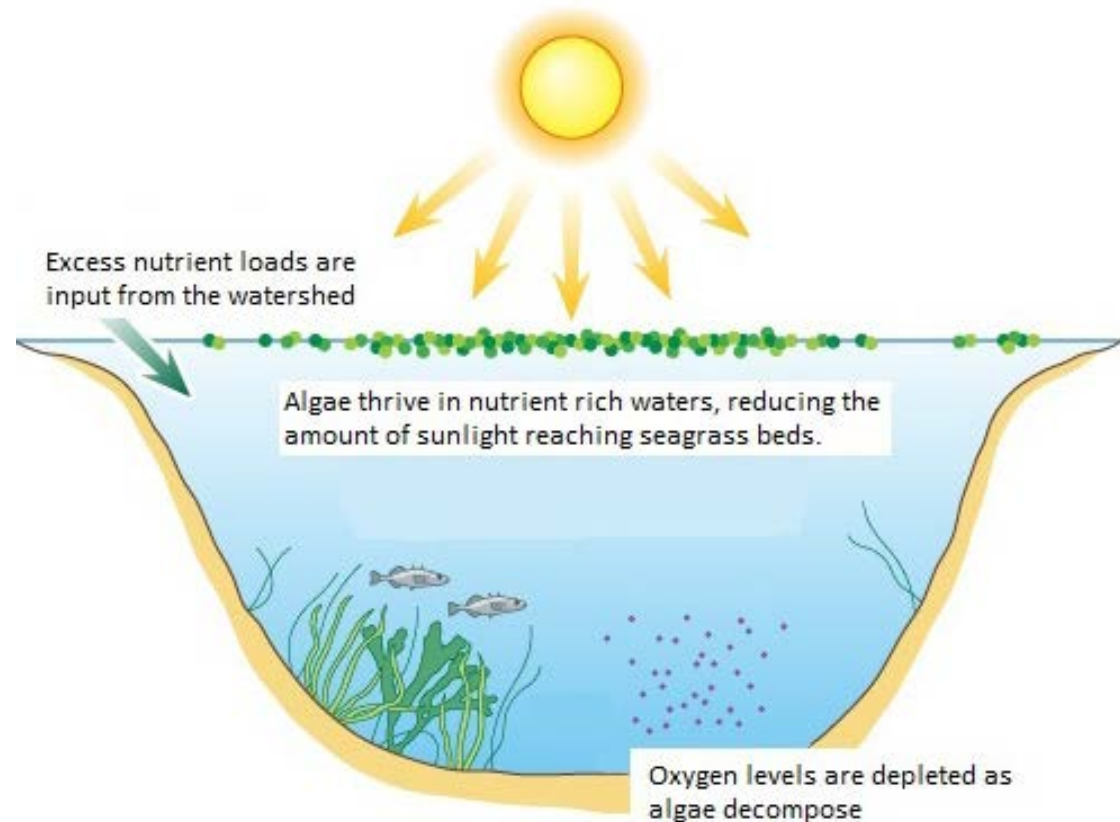
Tidal exchange from two breaks in barrier beach

- Barrier beach/inlet system is a dynamic feature
- South inlet formed in 1987
- North inlet formed in 2007
 - Initial increase in tidal exchange throughout the Bay system (USACE 2008)
- Recent tide data show decreasing tide range at the southern inlet due to shoaling
- System is moving toward a single dominant inlet (north inlet) that migrates southward over time (Giese 2010).



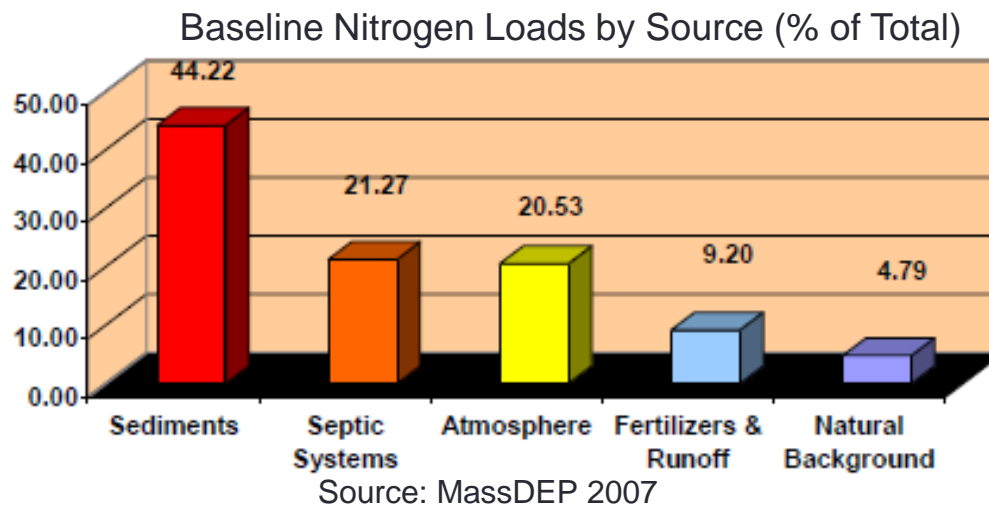
Nutrient loading to Pleasant Bay has contributed to degraded aquatic habitat

- Eutrophication = Enrichment of a waterbody with nutrients and the corresponding ecosystem responses
- Ecosystem responses may include:
 - Increased algal blooms
 - Reduced water clarity
 - Dieoff of seagrass beds
 - Odors/scums
 - Depleted dissolved oxygen
 - Reduced wildlife diversity
 - Fish kills



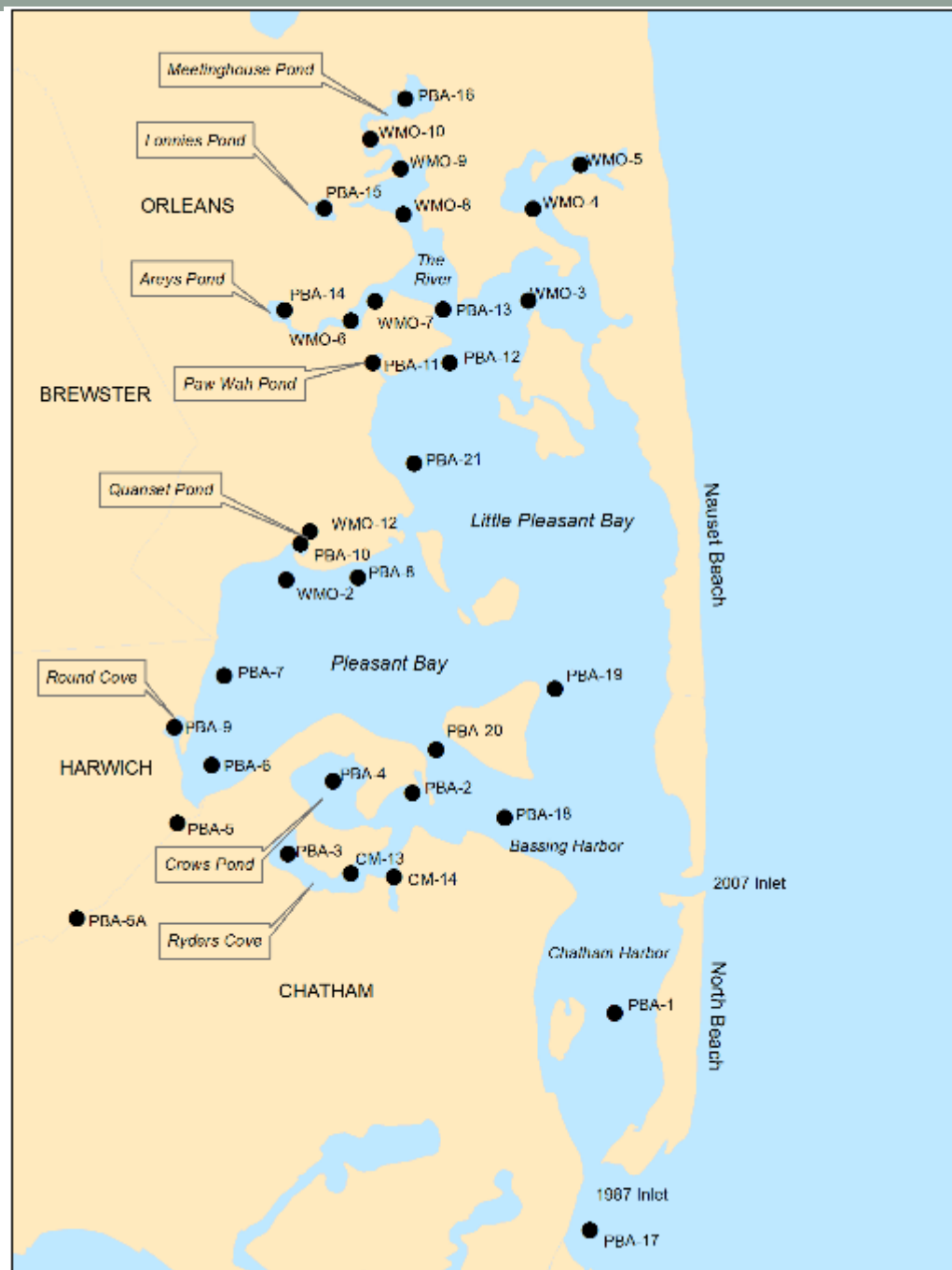
2007 Total Maximum Daily Load (TMDL) prescribed nitrogen budget for Pleasant Bay to improve habitat quality

- Nitrogen is the limiting nutrient for growth of aquatic plants & algae in estuarine systems.
- Major sources of nitrogen to Pleasant Bay include:
 - Onsite wastewater treatment (septic) systems
 - Runoff
 - Atmospheric deposition
 - Internal sediment release



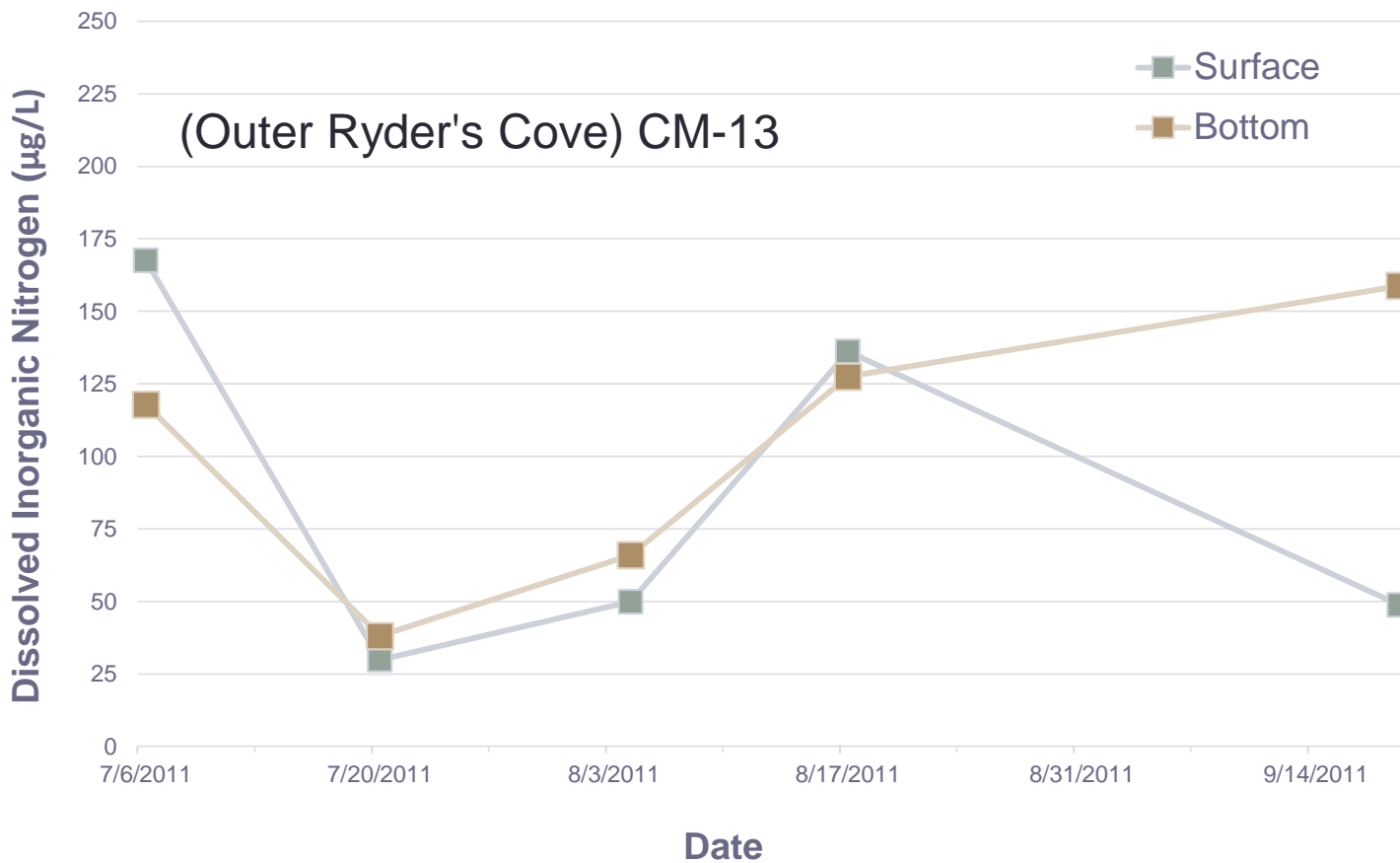
Water Quality Monitoring

- 34 monitoring stations throughout the main basin and sub-embayments
- Samples collected from 2000 through 2014
- Minimum sampling frequency is twice in July and August and once in September



Each sample is a snapshot of water quality at a specific location & moment in time...

- High temporal and spatial variability
- Example: 2011 dissolved inorganic nitrogen samples at station CM-13 range from 30-167 $\mu\text{g/L}$



Trend Analysis Objectives

- Use 2000-2014 monitoring data to characterize changes over time in:
 1. Dissolved Inorganic Nitrogen (DIN)
 2. Bioactive Nitrogen (BioN)
 3. Total Nitrogen (TN)
 4. Phosphate
 5. Total Phytopigments
 6. Dissolved Oxygen
 7. Salinity
- Station-specific trends
 - Analyze samples from each station individually
- Bay-wide trends
 - Analyze samples from all stations together

Description of Nitrogen Parameters

- Nitrogen cycles between inorganic and organic forms in the water column and sediment

Dissolved Inorganic Nitrogen =
Readily available for plant uptake (Nitrate, Nitrite, Ammonia)

Bioactive Nitrogen =
Inorganic Nitrogen + Bioavailable Organic Nitrogen

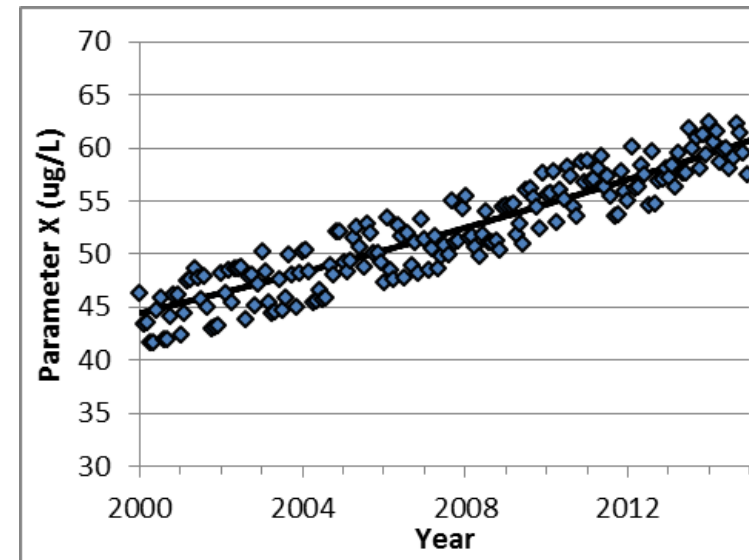
Total Nitrogen =
All forms (Inorganic Nitrogen + Organic Nitrogen)

Other Parameters Analyzed

- Phosphate = secondary nutrient for aquatic plant growth
- Total Phytopigments = ecosystem response parameter, indicator of algal growth
- Dissolved Oxygen = ecosystem response parameter, adequate levels necessary for healthy plant & animal communities
- Salinity = indicator of freshwater-saltwater balance

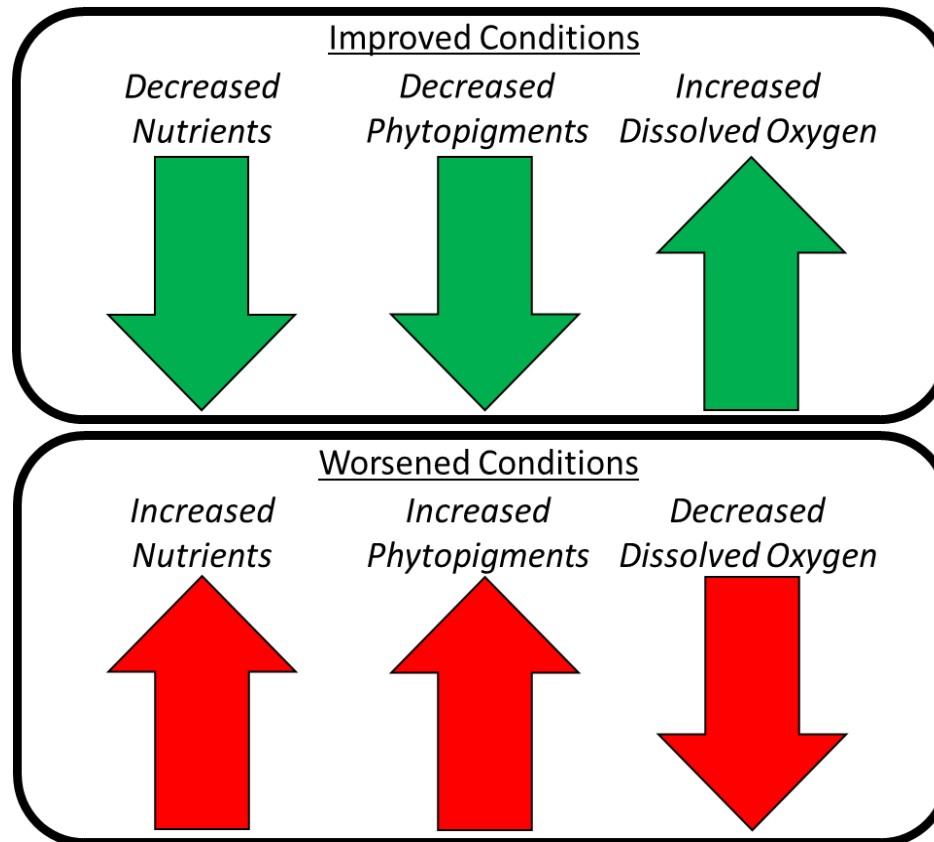
Trend Analysis Methods

- Fit trendline to sample data
- Evaluate statistical significance
 - Does trendline reflect a true trend over time or random variation in sample data?
- Trend analysis methods account for:
 - Variability in other covariates (sample depth, water temperature, etc.) to isolate trends over time
 - Station-to-station variability for isolating bay-wide trends
 - Potential changes in trends following the 2007 barrier beach break



Interpreting Trend Analysis Results

- Trends provide evidence of improved or worsened conditions



- “No significant trend” = Inconclusive result not stable conditions

Trend analysis provides information on changes over time

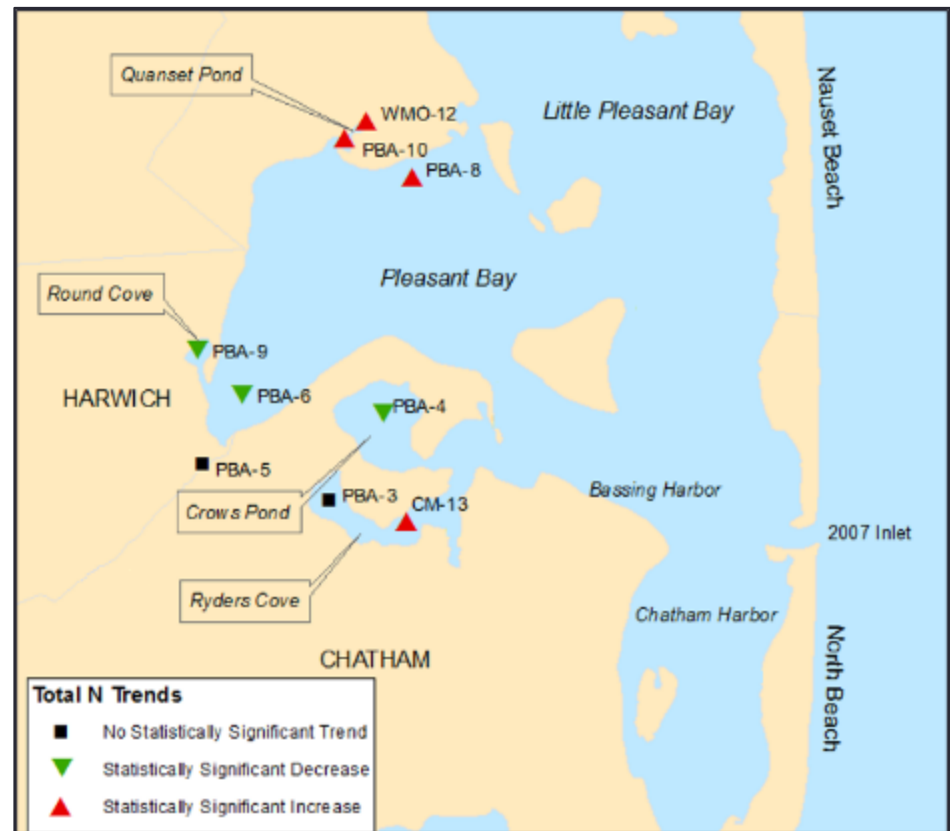
- Trends analysis results can be used to:
 - Gauge progress toward water quality goals
 - Evaluate whether changes expected to result from restoration actions have occurred
 - Highlight potential problem areas for restoration planning

Trend analysis provides information on changes over time

- Limitations of trend analysis results:
 - Not intended for making absolute statements on healthy vs. unhealthy conditions
 - Need to compare sample data to targets/thresholds associated with healthy conditions
 - Do not provide conclusive evidence of the causes of change.
 - Example: A decreasing trend in total nitrogen concentrations could be caused by reduced watershed N loads, reduced sediment N release, or increased exchange of ocean water following the 2007 break
 - Past trends do not predict the future. Reflect 2000-2014 sample data only.

Station-Specific Results

- Trends vary across stations for each parameter
- Example: Total Nitrogen
 - Increasing trend at 4 stations
 - Decreasing trend at 9 stations
 - No significant trend at 7 stations



No stations have improved trends across all six eutrophication parameters...

- But detected trends at some stations are consistent with improvement. Four stations have:
 - Decreased bioactive N and/or total N
 - Decreased phytopigments

Station	Dissolved Inorganic N	Bioactive N	Total N	Phosphate	Pigments	Dissolved Oxygen
Paw Wah Pond (PBA-11)	■	▼	▼	■	▼	■
Meetinghouse Pond (PBA-16)	■	▼	■	■	▼	■
Pochet Mouth (WMO-3)	■	▼	▼	■	▼	■
Namequoit River Mid (WMO-6)	■	▼	▼	■	▼	■

▼ = Decrease

■ = No significant trend

No stations have improved trends across all six eutrophication parameters...

- But detected trends at some stations are consistent with improvement. Four stations have:
 - Decreased bioactive N and/or total N
 - Decreased phytopigments
- Three additional stations also have trends of increased dissolved oxygen

Station	Dissolved Inorganic N	Bioactive N	Total N	Phosphate	Pigments	Dissolved Oxygen
Big Bay-SW (PBA-6)	■	■	▼	▼	▼	▲
Namequoit-South (PBA-12)	■	▼	▼	▼	▼	▲
River at Rattles Dock (WMO-10)	■	▼	▼	■	▼	▲

▼ = Decrease

■ = No significant trend

▲ = Increase

No stations have worsening trends across all six eutrophication parameters...

- One station has trends that are consistent with worsened conditions
 - Increased dissolved inorganic N, bioactive N, and total N
 - Reduced dissolved oxygen

Station	Dissolved Inorganic N	Bioactive N	Total N	Phosphate	Pigments	Dissolved Oxygen
Little Quanset Pond (WMO-12)	▲	▲	▲	■	■	▼

▲ = Increase

■ = No significant trend

▼ = Decrease

Many stations have inconsistent trends...

- Increase in some nutrient parameters but decrease in others
 - Example: Round Cove (PBA-9)

Station	Dissolved Inorganic N	Bioactive N	Total N	Phosphate
Round Cove (PBA-9)	▲	▼	▼	■

- Increase in nutrient parameters but improvements in response parameters
 - Example: Outer Ryder's Cove (CM-13)

Station	Dissolved Inorganic N	Bioactive N	Total N	Phosphate	Pigments	Dissolved Oxygen
Outer Ryder's Cove (CM-13)	▲	■	▲	▲	▼	▲

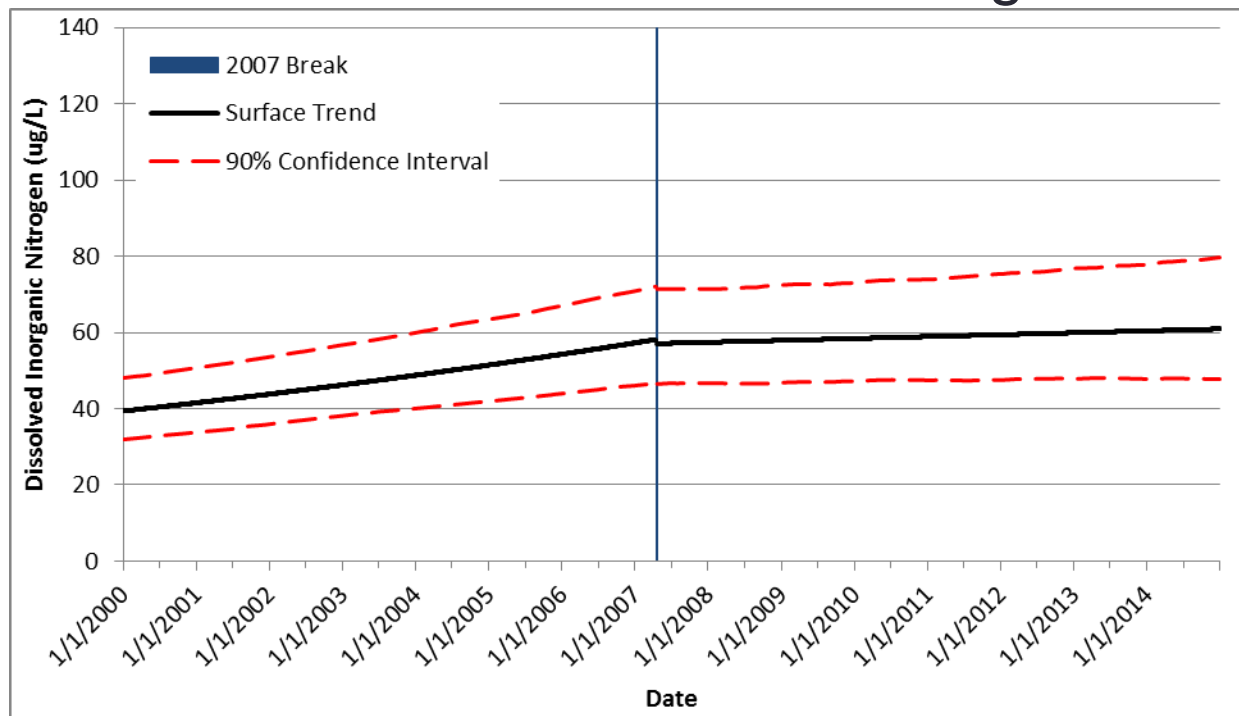
Takeaways from station-specific trends...

- Trends vary across Pleasant Bay monitoring stations
- Detected trends are consistent with improvement at seven stations
 - Big Bay-SW, Paw Wah Pond, Namequoit-South, Meetinghouse Pond, Pochet Mouth, Namequoit River Mid, and River at Rattles Dock
- Detected trends are consistent worsened conditions at one station
 - Little Quanset Pond
- Stations with coupled trends of increased nitrogen concentrations but improved phytopigments & dissolved oxygen merit further investigation

Bay-Wide Results

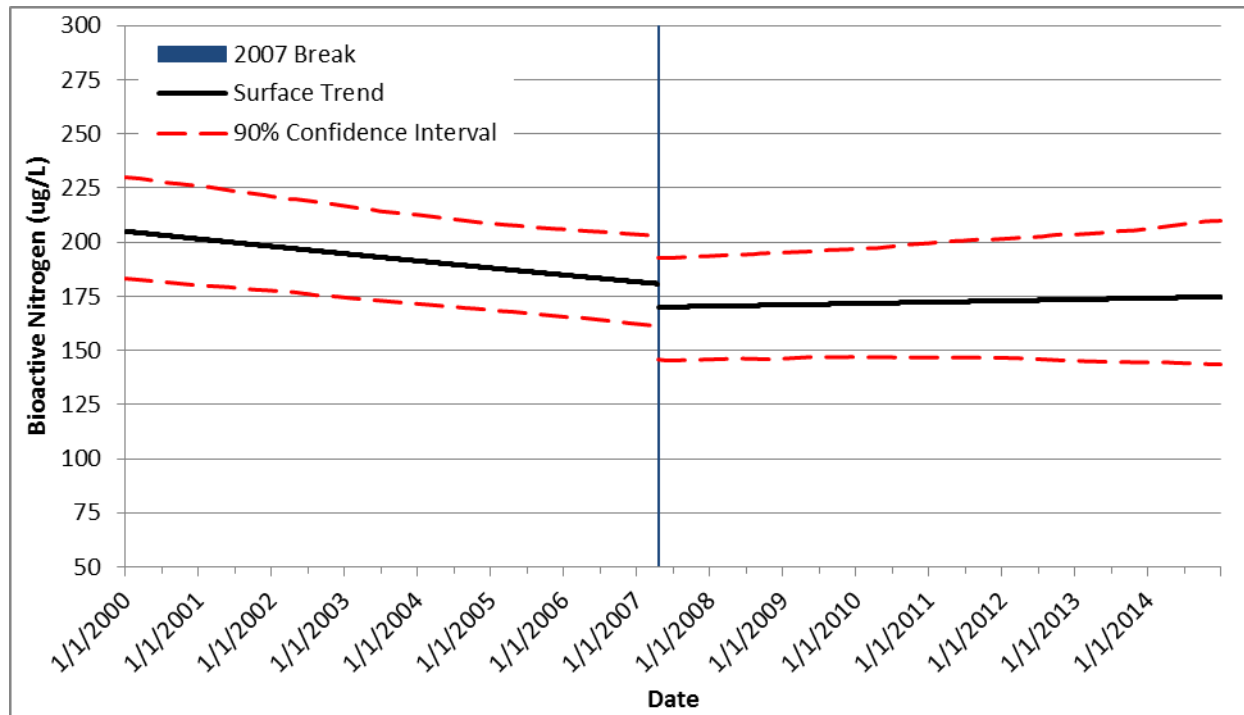
Dissolved Inorganic Nitrogen

- Increasing trend before 2007 break
- After break concentrations still increasing but at lower rate



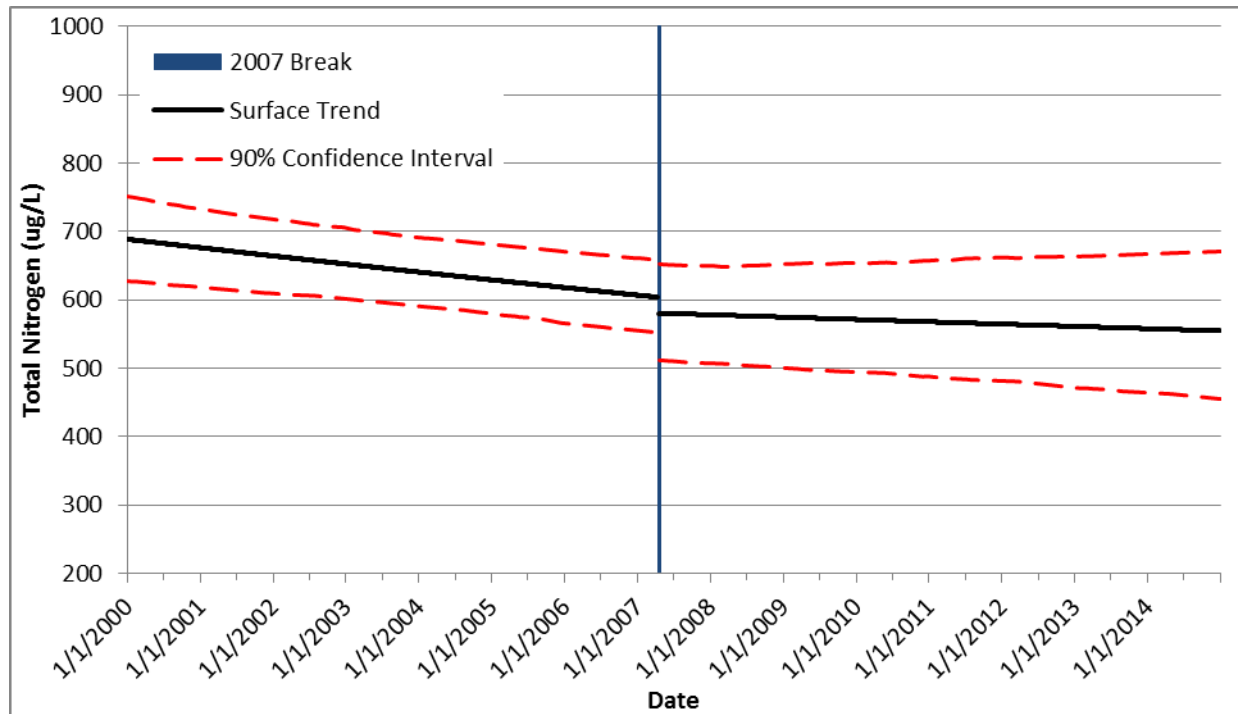
Bioactive Nitrogen

- Decreasing trend before 2007 break
- Increasing trend after break



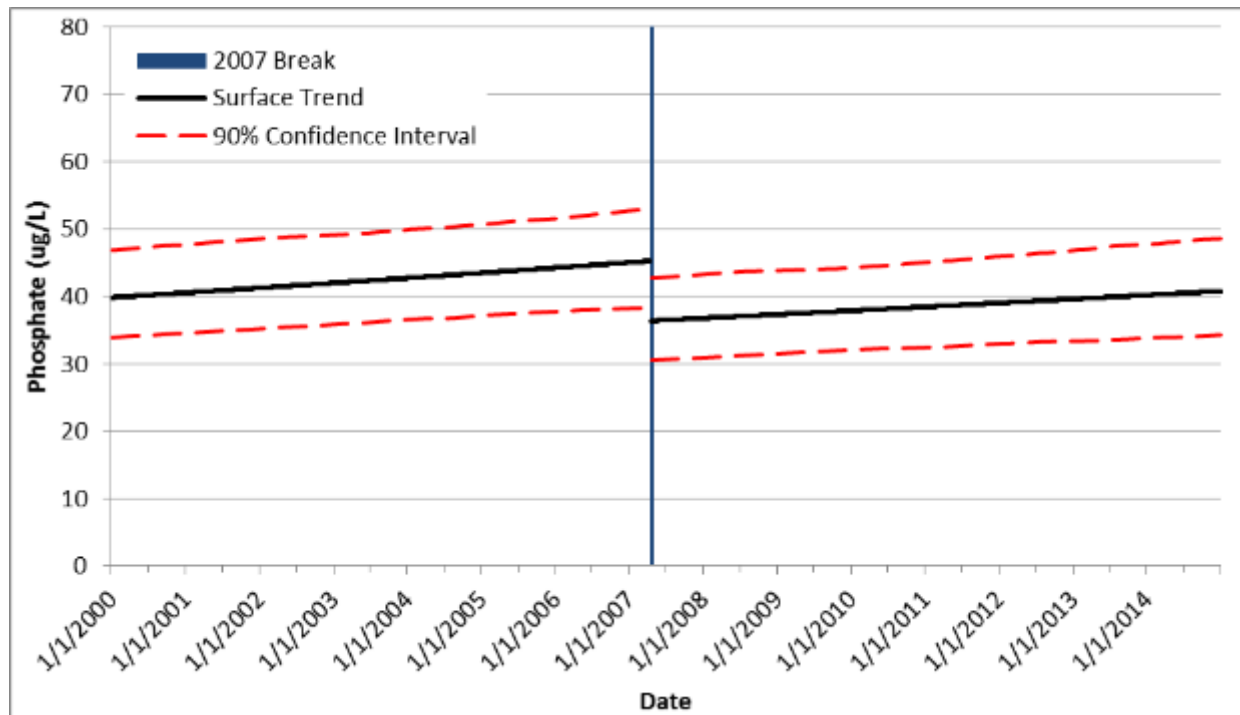
Total Nitrogen

- Decreasing trend before 2007 break
- No significant trend after break



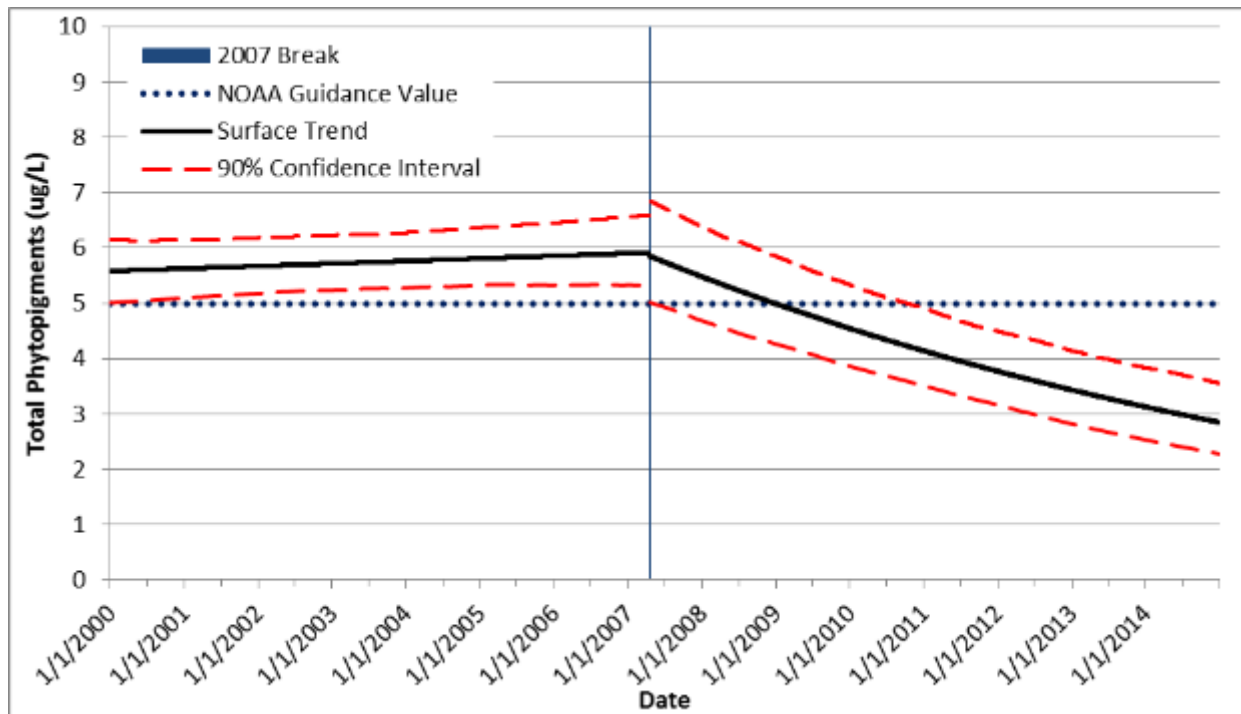
Phosphate

- Increasing trend before 2007 break
- No significant trend after break



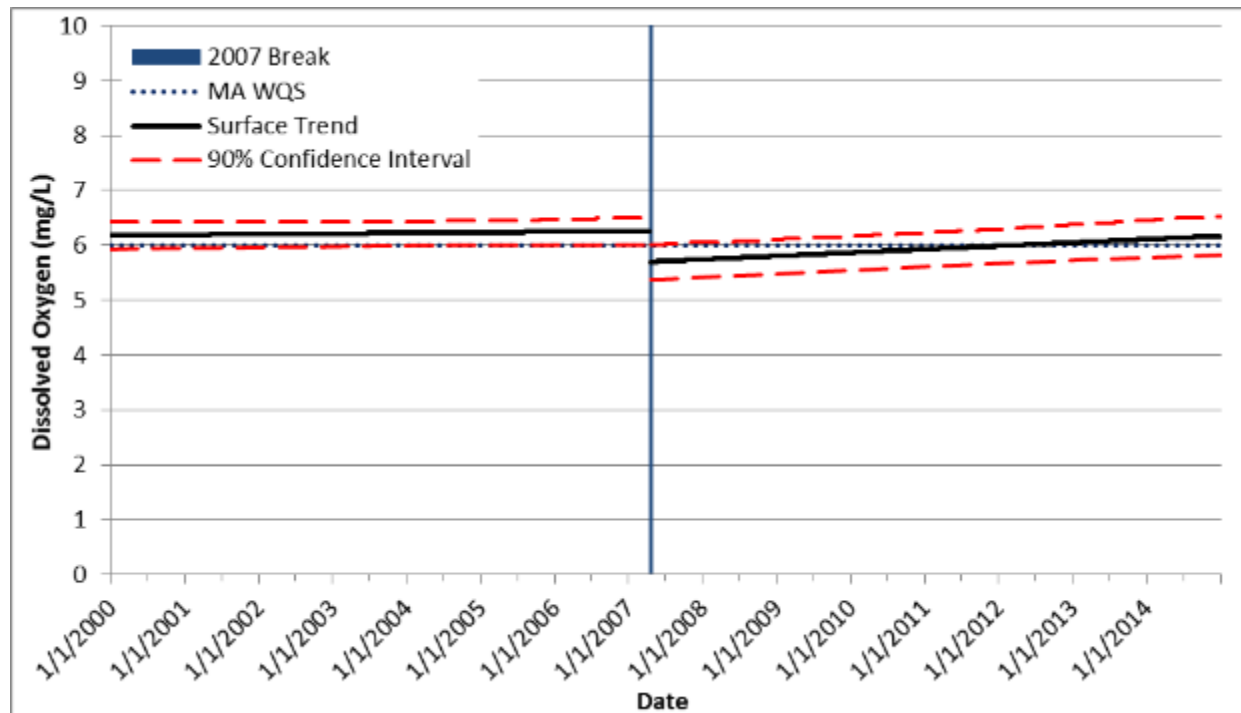
Total Pigments

- No significant trend before 2007 break
- Decreasing trend after break



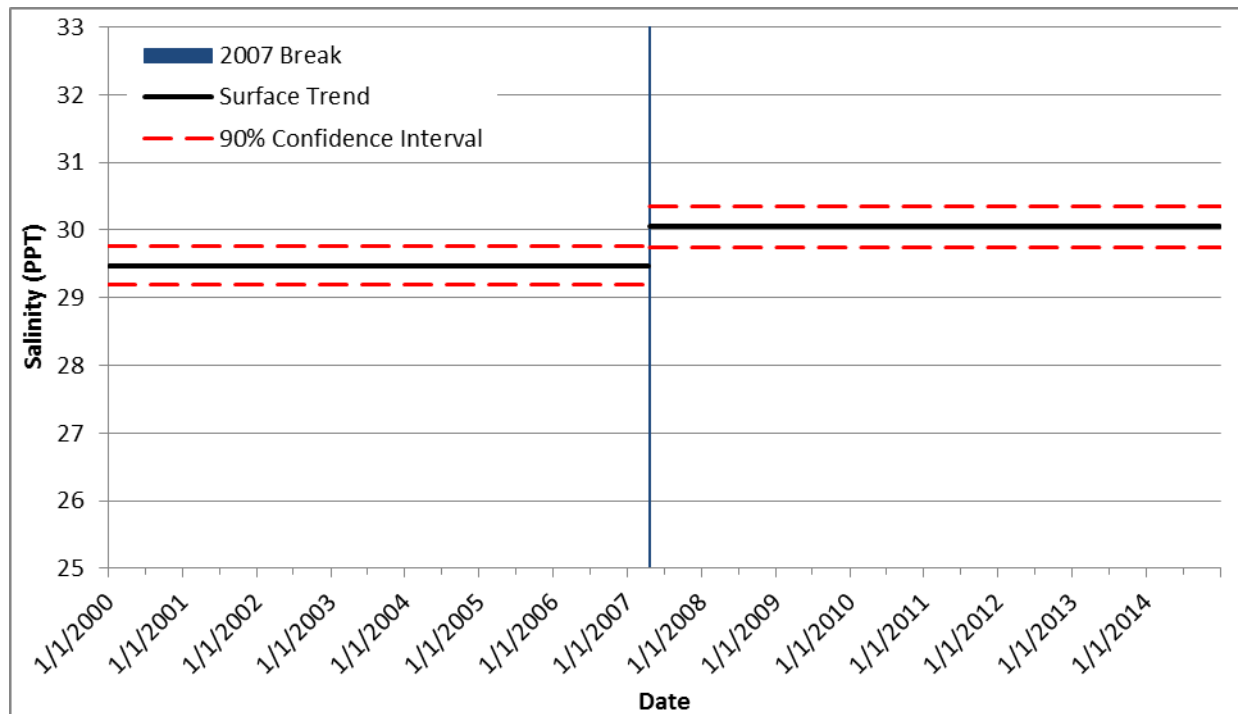
Dissolved Oxygen

- No significant trend before 2007 break
- Increasing trend after break



Salinity

- Higher concentrations after 2007 break



Summary of post-break trends...

- Increased dissolved inorganic nitrogen and bioactive nitrogen
- Decreased phytopigments
- Increased dissolved oxygen

Parameter	Post-Break Trend
Dissolved Inorganic Nitrogen	▲
Bioactive Nitrogen	▲
Total Nitrogen	■
Phosphate	■
Total Phytopigments	▼
Dissolved Oxygen	▲

Takeaways from bay-wide trends...

- Evidence of increased nitrogen enrichment in the Pleasant Bay system since the 2007 break
- Trends of increased nitrogen (DIN and bioactive N) but improved phytopigments & dissolved oxygen highlight complexity of the Pleasant Bay ecosystem
 - Additional factors influence algae growth (light, water clarity, pH) and changes in these factors may have outweighed effect of higher nitrogen concentrations

Next Steps...

- Further study needed to investigate drivers of change in nutrient and response parameters.
- Possible drivers include changes in:
 - Watershed nitrogen loading
 - Sediment nitrogen release
 - Tidal flushing
 - Other physical properties (pH, water clarity, etc.)

Questions?

- Full report available online: <http://pleasantbay.org/>