Developing automated, customizable reporting tools for the NERRS System Wide Monitoring Program

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National Estuarine Research Reserve System (NERRS)

29 Reserves
Protect and Study
NOAA – State Partnerships
System-Wide Monitoring Program (SWMP)

Long-term monitoring

• 1995 to present
• Uniform equipment
• Consistent approach and oversight
• Community driven standards and protocols
• Rigorous, consistent QA/QC approach and flags

Four water quality stations

• T, S, pH, DO, Turbidity, Depth
• Automated, 15-minute

Four nutrient stations

• Chl, NO2, NO3, NH4, PO4
• Monthly grab samples

Meteorology station

• Temp, Press, Winds, RH, Precip, Light
The Issue: Too much data!

Challenges

• Never enough time
• Never enough money
• Staff turnover
• Varying technical ability
• 29 different sets of interests

Solution Requirements

• An automated analysis process
• Must be “easy”
• Needs system-wide buy-in
The Solution

Committees!

- Technical Advisory Comm.
  - Keep graphics and plots credible
- Product Advisory Comm.
  - Design product
  - Define audience(s)
- Both
  - Testing and outreach

Solution

- Multi-step process
- Flexible template
- Robust R package

Highlights

- Little R knowledge needed
- Majority of work in Excel and PowerPoint
Workflow

Automated
• 1000+ plots generated(?)
• RStudio script
• PowerPoint draft

Manual
• Determine story
• Edit Excel spreadsheet
• Launch RStudio script
• Edit PowerPoint
• Save as PDF for printing
We Set the Theme, They Tell The Story

ESTUARY TRENDS: WEATHER & WATER QUALITY

Resilient estuaries and coastal watersheds where human and natural communities thrive.

Great Bay National Estuarine Research Reserve (NERR)

This reserve is a complex embayment and New Hampshire’s largest estuarine system, encompassing all of Great Bay and Little Bay, as well as the tidal portions of five major river systems: Bellamy, Oyster, Lamprey, Squamscott, and Winnipesaukee. The Great Bay Reserve includes diverse land and water areas, including upland forest, salt marsh, mudflats, tidal creeks, rocky intertidal, eelgrass beds, and upland field habitats. The Bay’s cultural heritage is equally diverse, from paleo-Indian villages dating to 6,000 years ago to colonial transportation and industrial use, to a proposed oil refinery in 1973. For more information go to: http://greatbay.org/

2016 HIGHLIGHTS

It was dryer - precipitation was below the long-term historical average

It was warmer - late winter/early spring air temperatures were higher than the long-term historical average

The highest observed inorganic nitrogen (DIN) concentrations occurred in the rainy winter season at two out of four locations

An algal bloom occurred in the summer at one out of four locations

Weather & Climate - What is the Difference?

WEATHER is what you see outside on any particular day in terms of precipitation, temperature, humidity, cloudiness, visibility and wind.

CLIMATE tells us the average daily weather for an extended period of time (years, decades, centuries) at a certain location.

Weather can have a major impact on water quality, precipitation, and air temperature.

Water quality issues influence human and environmental health. The more we monitor our water, the better we will be able to recognize and prevent problems.
# Excel Template – Overall Parameters

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### Excel Templates – Yearly Changes

<table>
<thead>
<tr>
<th>Variable_Name</th>
<th>Type</th>
<th>Description</th>
<th>Change</th>
<th>Text</th>
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</thead>
<tbody>
<tr>
<td>txt_cs_ttl</td>
<td>text</td>
<td>Title for nutrients page</td>
<td>No</td>
<td>Do We Have Too Many Nutrients In The Water?</td>
</tr>
<tr>
<td>txt_cs_intro</td>
<td>text</td>
<td>Descriptive text to intro</td>
<td>Yes</td>
<td>Phytoplankton (also called microalgae) are tiny, plant-like organisms that need nutrients (nitrogen and phosphorus) to grow. Phytoplankton are critical to estuarine and ocean health. However, some conditions, such as excess nutrients, can cause phytoplankton blooms. The blooms can decrease the dissolved oxygen underwater life needs to survive, negatively impact human health, and close fishery harvest areas.</td>
</tr>
<tr>
<td>txt_cs_plot_ttl_1</td>
<td>text</td>
<td>Title for the top plot</td>
<td>Yes</td>
<td>Nitrogen</td>
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<tr>
<td>txt_cs_plot_caption_1</td>
<td>text</td>
<td>Caption for the top plot</td>
<td>Yes</td>
<td>Dissolved inorganic nitrogen (DIN) is the type of nitrogen in the water phytoplankton need to grow. At Elkhorn Slough NERR, data show that DIN concentrations are not changing over the long-term. Most of the measurements are in the fair to good range. However, the critical threshold of 0.5 mg/L is exceeded and usually, during the winter rainy season.</td>
</tr>
<tr>
<td>txt_cs_plot_ttl_2</td>
<td>text</td>
<td>Title for the bottom plot</td>
<td>Yes</td>
<td>Algae</td>
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<td>txt_cs_plot_caption_2</td>
<td>text</td>
<td>Caption for the bottom plot</td>
<td>Yes</td>
<td>Phytoplankton growth is measured by chlorophyll a concentrations. At Elkhorn Slough NERR, data show that chlorophyll a levels are not changing over the long-term. Most of the measurements are in the fair to good range. Concentrations exceed the critical threshold of 20 ug/L, at times, at all sampling locations. Concentrations most often exceed the critical threshold at North Marsh.</td>
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<tr>
<td>txt_cs_map_ttl</td>
<td>text</td>
<td>Title for trend map</td>
<td>Yes</td>
<td>How is Oxygen Changing?</td>
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<tr>
<td>txt_cs_map_caption</td>
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<td>Caption for trend map</td>
<td>Yes</td>
<td>Dissolved oxygen increased at North Marsh and South Marsh. Most of the measurements vary between the poor to good range at all locations.</td>
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<td>txt_cs_outreach_tt</td>
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<td>Small Changes You Can Make To Help</td>
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<td>txt_cs_outreach_point_1</td>
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<td>Outreach option #1</td>
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<td>Limit use of fertilizers/pesticides and apply responsibly</td>
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<tr>
<td>txt_cs_outreach_point_2</td>
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<td>Outreach option #2</td>
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<td>Use compost as fertilizer in gardens</td>
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<tr>
<td>txt_cs_outreach_point_3</td>
<td>text</td>
<td>Outreach option #3</td>
<td>Yes</td>
<td>Collect pet droppings</td>
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</tbody>
</table>

**Office for Coastal Management**
Build on SWMPr:
Retrieve, Organize, and Analyze Estuarine Data

SWMPrExtension: More Functions to Retrieve, Organize, and Analyze Estuarine Data

Retrieve

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>all_params</td>
<td>Retrieve any number of records starting with the most recent at a given station, all parameters. Wrapper to exportAllParams function on web services.</td>
</tr>
<tr>
<td>all_params_straing</td>
<td>Retrieve records of all parameters within a given date range for a station. Optional argument for a single parameter. Wrapper to exportAllParamsDateRange function.</td>
</tr>
</tbody>
</table>

Analyze

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>aggreswmp, swmp</td>
<td>Aggregate swmp objects for different time periods - years, quarters, months, weeks, days, or hours. Aggregation function is user-supplied but defaults to mean.</td>
</tr>
<tr>
<td>aggreswmp, swmp</td>
<td>Aggregate metabolism data from a swmp object. This is primarily used within plot_metab but may be useful for simple summaries of raw daily data.</td>
</tr>
<tr>
<td>annual_range.swmp</td>
<td>For a user-specified year, calculate averages, average ranges, and min/max observed ranges the on a monthly or seasonal basis.</td>
</tr>
<tr>
<td>historical_daily_range.swmp</td>
<td>Compare a user-specified year against historical data on a daily basis.</td>
</tr>
<tr>
<td>historical_range.swmp</td>
<td>Compare a user-specified year against historical data on a monthly/seasonal basis.</td>
</tr>
<tr>
<td>raw_boxplot.swmp</td>
<td>Generate a monthly/seasonal boxplot for parameters that are better viewed in on a cumulative basis (e.g. precipitation).</td>
</tr>
<tr>
<td>seasonal_barplot.swmp</td>
<td>Generate monthly/seasonal boxplots of daily average statistics (min/average/max) across a user-specified time period. Includes the option to calculate median value for a target year and include a line for a water quality threshold.</td>
</tr>
<tr>
<td>threshold_identification.swmp</td>
<td>Identify dates and times that a user-specified water quality threshold is exceeded. For continuous monitoring data, the user can also specify the length of time the threshold must be exceeded for the event to be included (e.g. DO must be &lt; 2 ppm for 3 days)</td>
</tr>
</tbody>
</table>
Easy Customization
Options are built into functions...

```r
x <- seasonal_boxplot(dat, param = 'do_mgl',
    hist_rng = c(2007, 2016),
    plot_title = T)

y <- seasonal_boxplot(dat, param = 'do_mgl',
    hist_rng = c(2007, 2016),
    season = list(c(1,2,3), c(4,5,6), c(7,8,9), c(10, 11, 12),
    season_names = c('Winter', 'Spring', 'Summer', 'Fall'),
    plot_title = T)
```

```r
x <- seasonal_boxplot(dat, param = 'do_mgl',
    hist_rng = c(2007, 2016),
    season_start = 'Oct',
    plot_title = T)
```
Easy Customization
Options are built into functions...

```r
x <- threshold_plot(dat_wq, param = 'do_mgl',
                      thresholds = c(2, 5),
                      threshold Labs = c('Poor', 'Fair', 'Good'),
                      monthly_smooth = T,
                      threshold_cols = c('#FEC596', '#FFFCCE', '#A8D9E9'))

x2 <- threshold_plot(dat_wq, param = 'do_mgl',
                      thresholds = c(2, 5),
                      threshold Labs = c('Daily', 'Pizza', 'Eat'),
                      monthly_smooth = T,
                      threshold_cols = c('khaki', 'bisque', 'wheat3'))
```
Why Do It This Way?

• Fits into the existing SWMPr framework
• Easy way to distribute R code
• Easy to document process
• One stop shop for basic customization
• Easier maintenance over time
• Flexibility to use outside of the “reserve template”
Example: Grand Bay
Page 1

- Introduce the Reserve
- Brief annual highlights

ESTUARY TRENDS: WEATHER & WATER QUALITY
Resilient estuaries and coastal watersheds – where human and natural communities thrive.

Grand Bay National Estuarine Research Reserve (NERR)
This reserve represents one of the most biologically productive ecosystems in the northern Gulf of Mexico. The habitat within the reserve supports rare and endangered plant and animal species, important marine fisheries, and archeological sites. The site encompasses black needle rush marshes, maritime pine forests, pine savanna, salt prairies and pools, and pitcher plant bogs. Many species of carnivorous plants and orchids are present in the higher savanna habitats. For more information go to:

http://grandbaynerr.org/

2017 HIGHLIGHTS

- It was wet - the annual rainfall total was the highest recorded by Grand Bay SWMP since monitoring started in 2004.

- Dissolved inorganic nitrogen (DIN) was in the good to fair range for all locations.

- An algal bloom occurred in the summer at three out of four locations.

Office for Coastal Management

Water quality issues influence human and environmental health. The more we monitor our water, the better we will be able to recognize and prevent problems.
Example: Waquoit Bay

Page 1

- Introduce the Reserve
- Brief annual highlights

Waquoit Bay National Estuarine Research Reserve (NERR)

This reserve is located on the south shore of Cape Cod, Massachusetts and contains open waters, salt and freshwater marshes, barrier beaches, sand dunes, rivers, mixed pine and oak forests, and sandplain grasslands.

Waquoit Bay, approximately 825 acres, is the dominant water feature and once supported one of the most diverse estuarine fish communities in the state. Waquoit Bay is still important to commercial and recreational shellfish and finfish fisheries. For more information go to:

http://www.waquoitbayreserve.org/

2016 HIGHLIGHTS

- It was drier - precipitation was below the long-term historical average

- It was hotter – August and September air temperatures were higher than the long-term historical average

Dissolved inorganic nitrogen (DIN) concentrations were low for most of the year at all locations

Consistent with previous years, an algal bloom occurred in the summer at the Childs River location

Water quality issues influence human and environmental health. The more we monitor our water, the better we will be able to recognize and prevent problems.
Example: Grand Bay
Page 2

This year’s story
Ex: Algal bloom and precipitation
Show trends that matter
Example: Waquoit Bay
Page 2

This year’s story
Ex: Timing of precipitation
Show trends that matter

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Example: Grand Bay Page 3

Choose graphs to tell story

Extra space for local message

What is an estuary?

An estuary is a semi-enclosed body of water with unique properties that allow for a dynamic ecosystem and environment. It’s where fresh and salt water meet. An estuary provides habitat for nurseries for ecologically and economically important species, is a great place for recreational activities like fishing, kayaking, and photography, and many other ecosystem services. The only constant thing about estuaries is that they’re always changing. The Grand Bay Estuary’s two water quality monitoring sites highlighted below show just how dynamic our estuary can be.

Salinity at Bayou Heron (more upland-influenced)

Bayou Heron is our most freshwater-influenced site. High rainfall causes both salinity and pH at this station to drop. The drop in pH is natural! The watershed is undeveloped, and full of pine trees - which cause the water to become darker in color and more acidic, just as tea leaves or coffee grinds cause water to run into these hot, tasty beverages. To see real-time data from this station (especially interesting during storms), visit http://nercdata.org and type in 'grndbhwn' for the station code.

Salinity at Bangs Lake (more marine-influenced)

Bangs Lake is our second-most saltwater-influenced site. Typical summer rain storms will cause salinity to decrease, but dropping below 8 ppt is uncommon. Additionally, the higher salinity at this site buffers it against pH changes; they are not dramatic like those at Bayou Heron.

How does changing salinity affect our waters?

- When there’s more water from higher rainfall, both salinity and pH go down.
- Changing salinity is a condition that some species have adapted to for living in an estuary, like some marsh plants and animals.
- Historical accounts mention the presence of productive oyster reefs, but today, the Grand Bay Estuary’s freshwater inflow, or sometimes lack thereof, may have an influence on why oysters are not as productive. In fact, in the early 1900s, residents of the Pecan community where the Grand Bay NERR is located, dug a canal from a nearby river to connect it to the estuary to try to increase freshwater input for oysters. It is an early example of local restoration efforts.

Water Quality is a MAJOR Driver of Ecosystem Change

What happens on the land affects the quality of the water and the health of the plants and animals that live in the estuary.
Example: Waquoit Bay
Page 3

Choose graphs to tell story
Extra space for local message

Office for Coastal Management
Example:
Grand Bay
Page 4

Uniform final page
Local contact info and branding

Office for Coastal Management
Example:
Waquoit Bay
Page 4

Why Estuaries Matter

### Economic Impacts
Coastal shoreline counties provided 53 million jobs and contributed $7.4 trillion (nearly 44%) of the nation’s gross domestic product in 2012.

### Community Benefits
Estuaries protect coastal communities by reducing flooding and storm surge impacts, enhancing water quality, and providing commercial and recreational benefits.

### Healthy Ecosystems
Up to two-thirds of the nation’s commercial fish and shellfish spend some part of their life cycle in an estuary or depend on this resource for food.

### Habitat Diversity
Habitat types include shallow open waters, freshwater/salt marshes, swamps, sandy beaches, mud/sand flats, rocky shores, oyster reefs, mangrove forests, river deltas, tidal pools and seagrasses.

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Tracking The Health of Our Estuaries 24/7

The NERRS is a partnership program between NOAA and the coastal states to manage designated reserves. More than 1.3 million acres of estuarine land and water are protected. Each reserve is managed on a daily basis by a lead state agency or university with input from local partners. The health of every reserve is continuously monitored by the System Wide Monitoring Program (SWMP). SWMP is a robust, long-term, and versatile monitoring program that uses the NERRS network to intensively study estuarine reference sites for evaluating ecosystem function and change. Reserve-generated data and information are available to local citizens and decision makers. For more information, go to: https://coast.noaa.gov/nerrs/

More Information...

For Stakeholders
Access data at the System Wide Monitoring Program (SWMP) Graphing Application website: https://coast.noaa.gov/swmp/

For Scientists
Access data at the Central Data Management Office (CDMO) website: http://www.nerrdata.org/

Have Questions?
Contact: Research Coordinator Megan.Tyrrell@state.ma.us
(508) 457-0495 x 105

Waquoit Bay NERR - providing the science needed for today and tomorrow
Key Benefits of Open Science for NERRS Reporting Tools

• Literally building on other people’s work
• Making your data even more readily accessible
• Providing a framework for others contributions into the future
• Increasing communication with the public while minimizing overhead

Photo Courtesy of Chesapeake Bay NERR – Maryland
Questions?

Dave.Eslinger@noaa.gov
843-740-1270

https://github.com/NOAA-OCM/SWMPrExtension
or
SWMPrExtension on CRAN