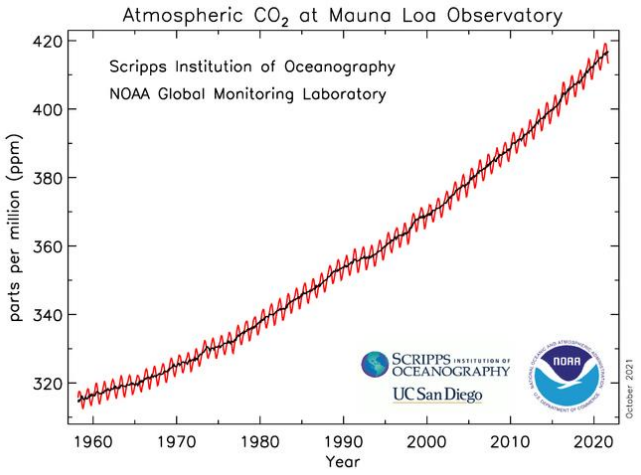
# Indicators: Examples, Applications, Options, and Translations

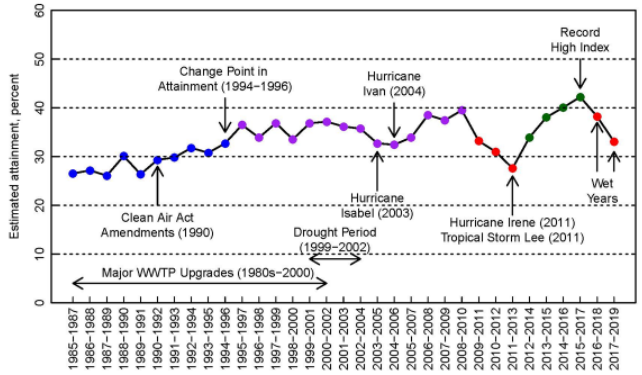
Peter Tango and Katheryn Barnhart

Status and Trends WG

November 12, 2021




Chesapeake Bay WQS Attainment Indicator (1985-2019)




*Zhang et al., Science of the Total Environment, 2018, 637: 1617-1625*

# Outline for today

- 10 minutes presentation:
  - Famous indicator example & WQ Stds Attainment Indicator example
- 10 minutes discussion #1:
  - How indicators can address part of our outcome needs

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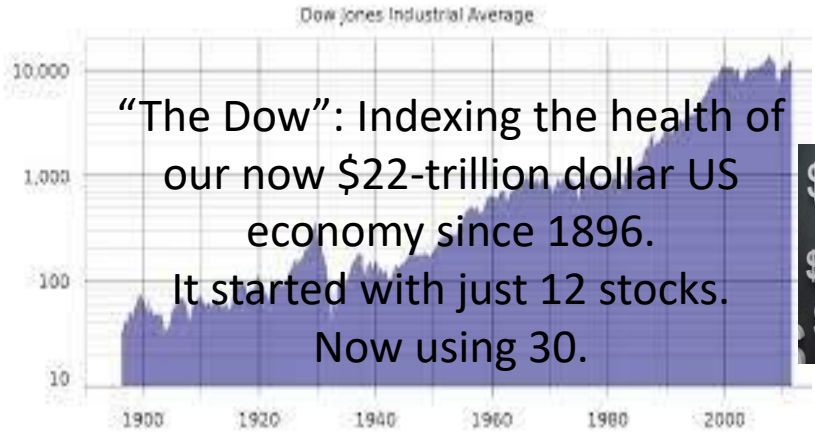
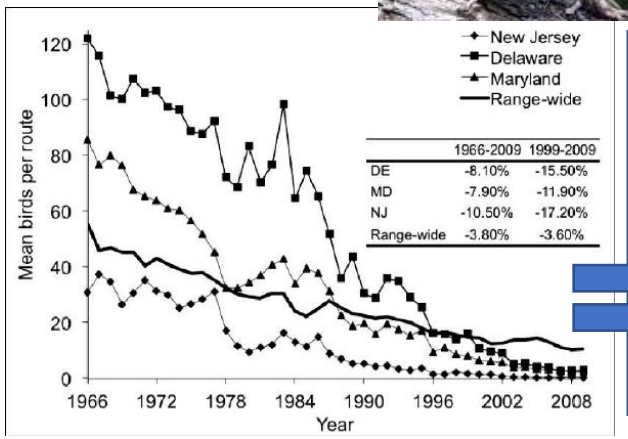
- 10 minutes presentation:
  - You can’t change what you don’t measure: Translating qualitative statements into quantitative measures.
- 15 minutes discussion #2:
  - Discussion on the concept of qualitative-quantitative translations for creating tracking measures to support communicating progress on your work.

# Let’s talk indicators

- Simple
- Reliably measured
- Repeatably measured
- Cost effective
- Science-based
- Relevant
- Relatable to management & policy




There are roughly 6000 tradable stocks. 30 = 0.5% of stocks are used for this famous economic indicator

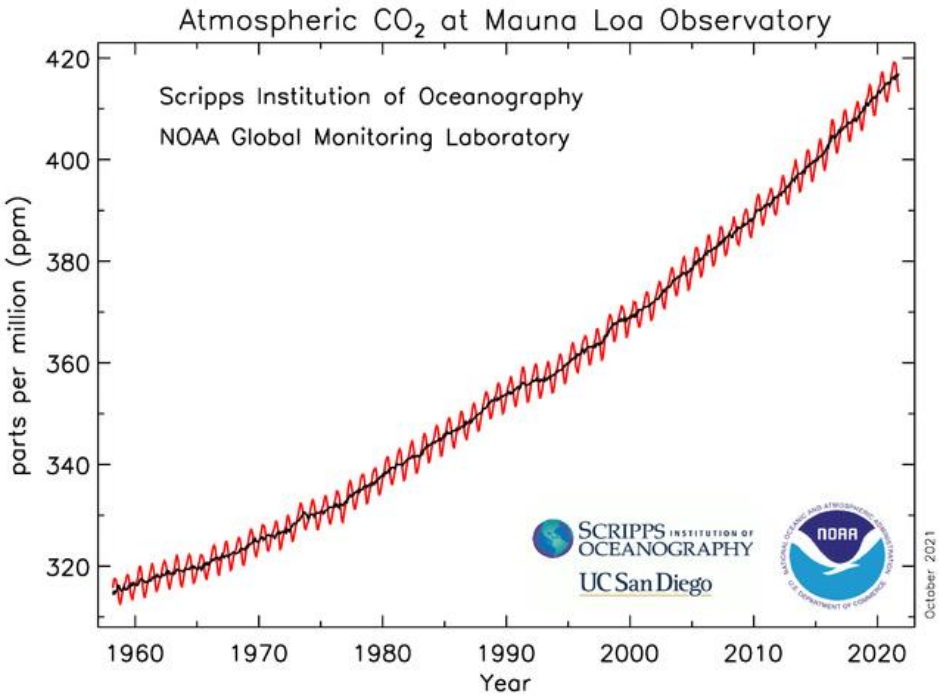

Hi cost, hi powered technical study

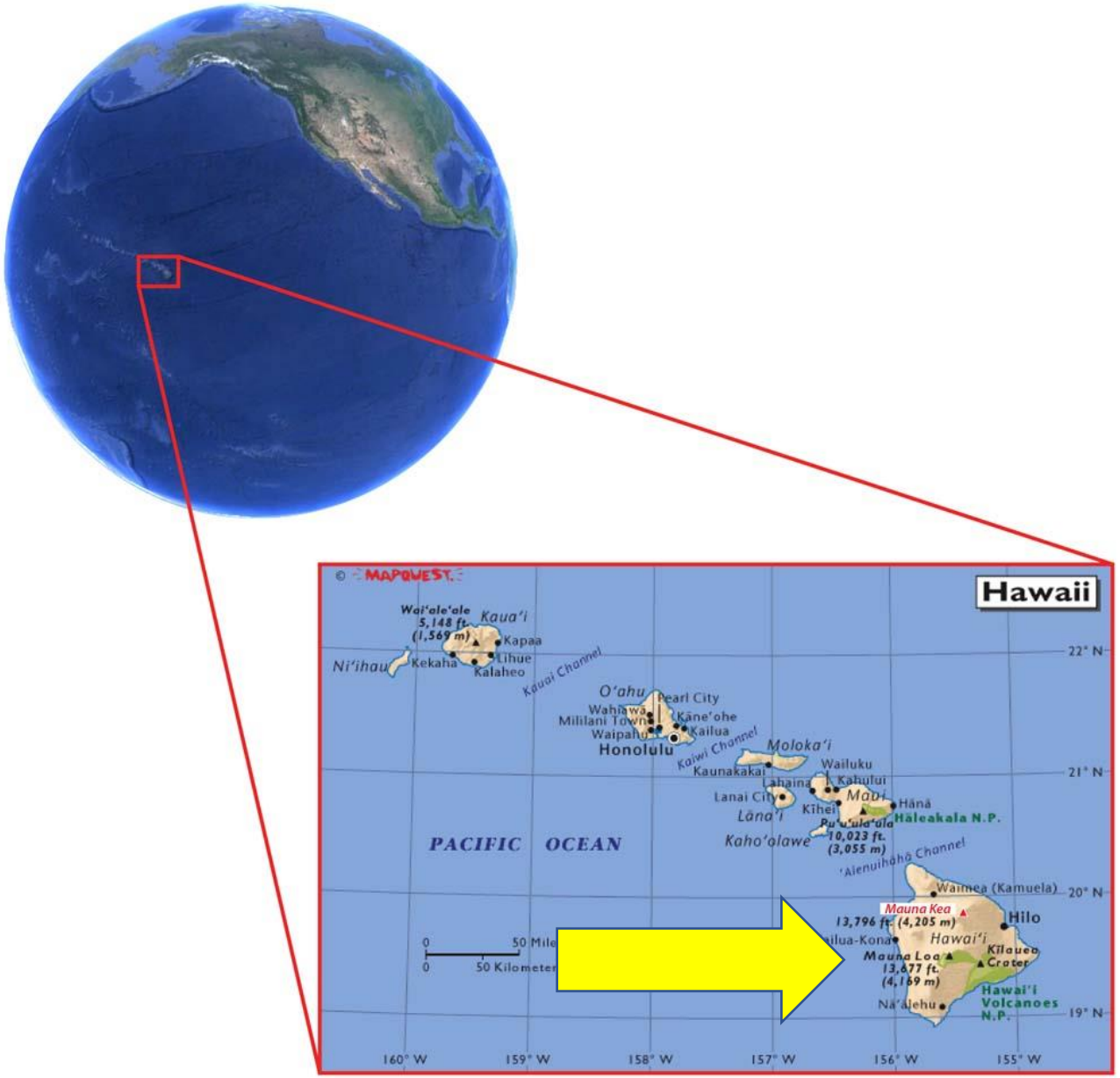
Maryland: Same trends for a fraction of the cost and effort using community science

Low cost, low intensity mail in survey of bow-hunter observations

# Famous indicators

- Keeling Curve: $CO_2$ in the atmosphere. 1 location.



# Why do we care about $CO_2$?

- "At the current rate of growth in $CO_2$, levels will hit 500 ppm within 50 years, putting us on track to reach temperature boosts of perhaps more than 3 degrees C (5.4°F) — a level that climate scientists say would cause:
  - bouts of extreme weather
  - sea level rise that threatens coastline, cultures and countries
  - endanger global food supplies
  - cause disruptive mass migrations, and
  - destroy the Amazon rainforest through drought and fire".

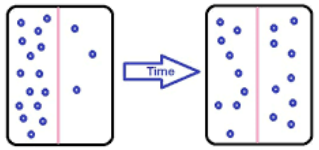
Reference: https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters Yale Environment (2017)

Not to mention the ocean acidification impacts of it all…

# Why do we care about $CO_2$?

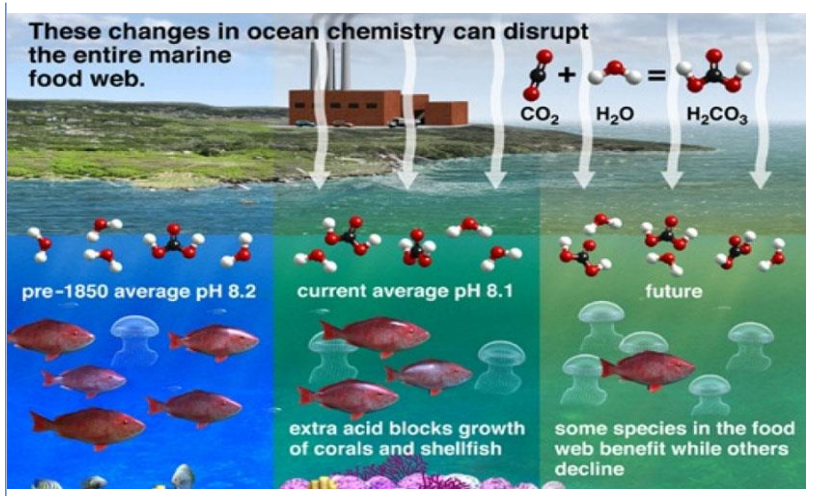
## Conceptual model:

- $CO_2$ is a greenhouse gas –
  - **Management relevant**, something we influence and can manage.
  - It is not the only greenhouse, **it is an indicator of a problem**.
- $CO_2$ is soluble in water.
  - More $CO_2$ in the air, diffusion occurs and there is more $CO_2$ in the water.
- With more $CO_2$ in the water, water becomes more acidic…
  - and pH goes down. (*Important because organisms are sensitive to pH conditions*.)

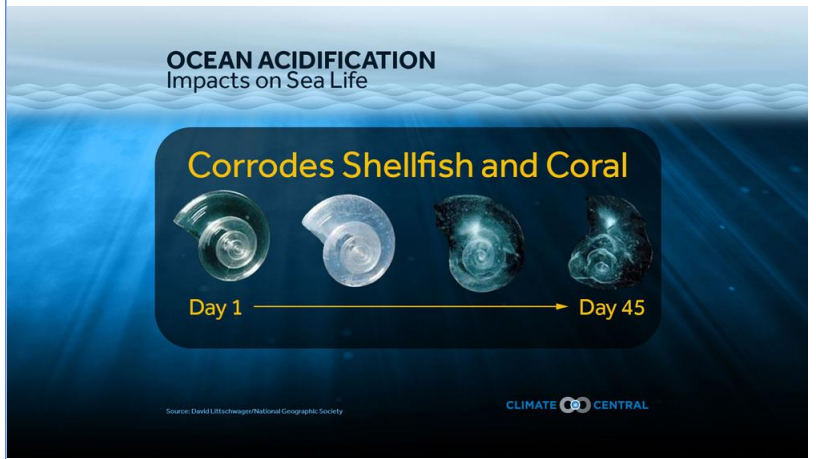





- Can we see the conceptual model play out in ocean chemistry with monitoring?

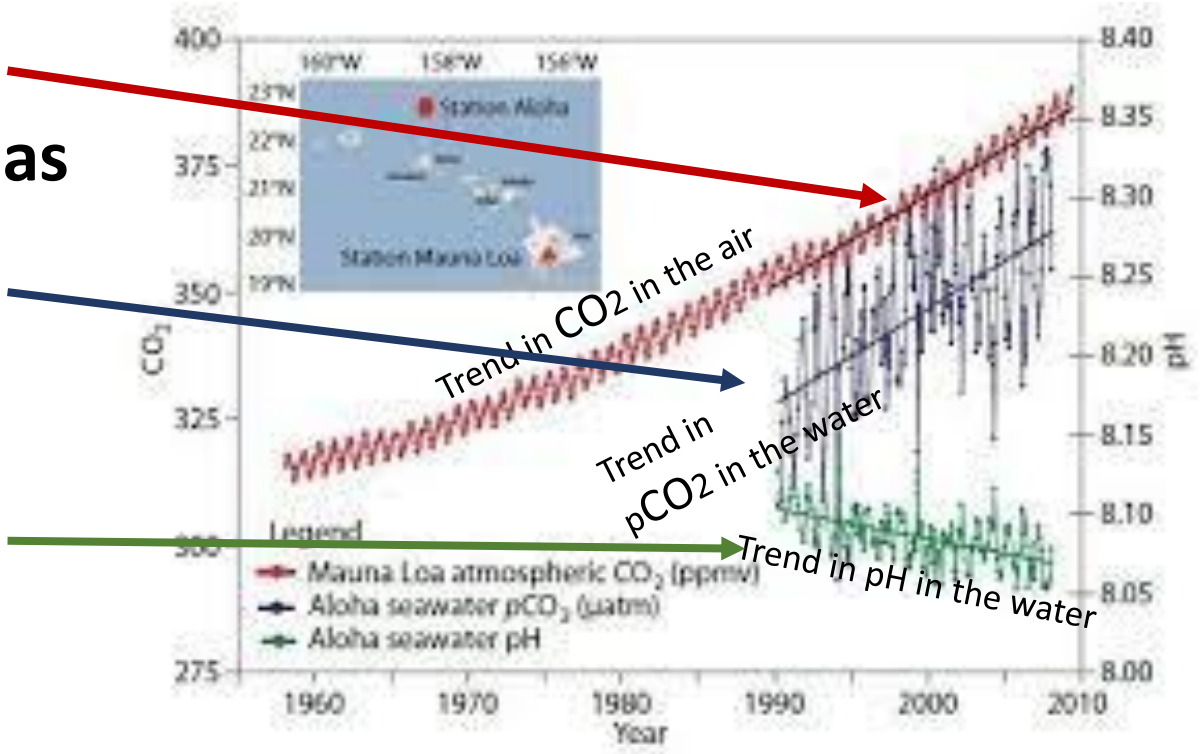






# The power of data. 1 location is worth 100 stations of data here. Same story everywhere.

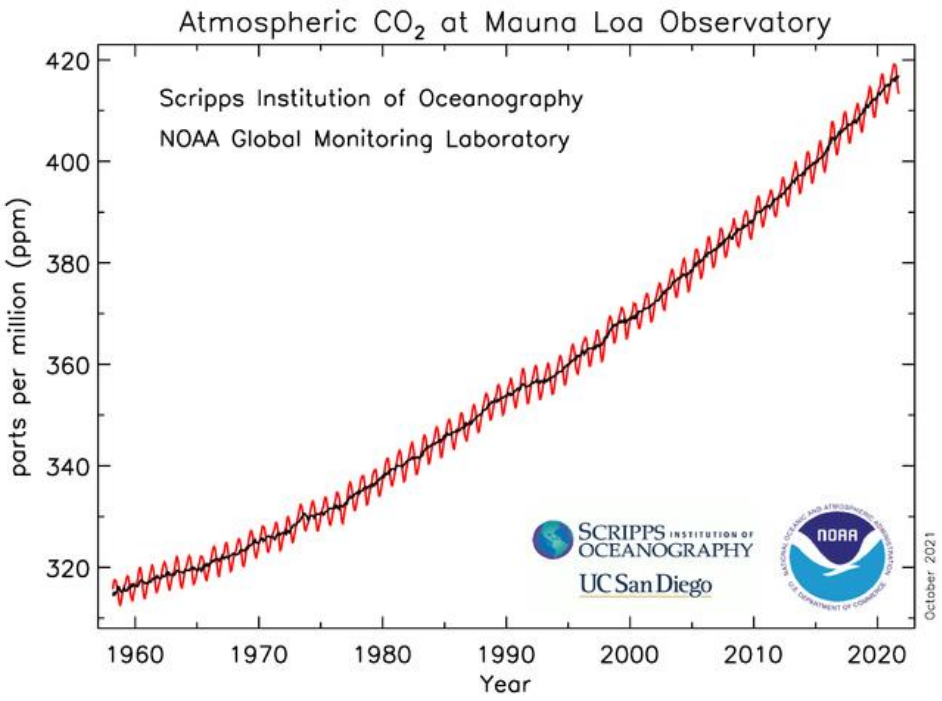
- $CO_2$ is steadily rising in the air.
- $pCO_2$ in the water is rising **just as we predict it should**.
- pH is declining because more $CO_2$ in the water creates more acidic conditions **just as we predict it should**.




***Science further shows use these patterns are consistent with measures made around the world. **Same message with 100 monitoring stations as you have with 1 station**.

## REMINDER: Important Indicator Qualities

| |
|---|
| **Simple and easy to understand** |
| Be scientifically well-founded |
| Have a reference or threshold value of significance |
| Be responsive to changes in the environment |
| Show trends over time |
| **Feasible to measure and report (reasonable cost/benefit ratio)** |
| **Updated regularly with reliable procedures (timely with support of a monitoring program)** |
| Adequately documented, known quality |
| Be useable by the community |
| Policy relevant |



# Chesapeake Bay Water Quality Standards Attainment Indicator

Qian Zhang, Peter Tango, Richard Tian, Mike Mallonee, Durga Gosh

There are **92 segments in the tidal waters of the bay**.
We have **156 monitoring stations operating since 1985**.

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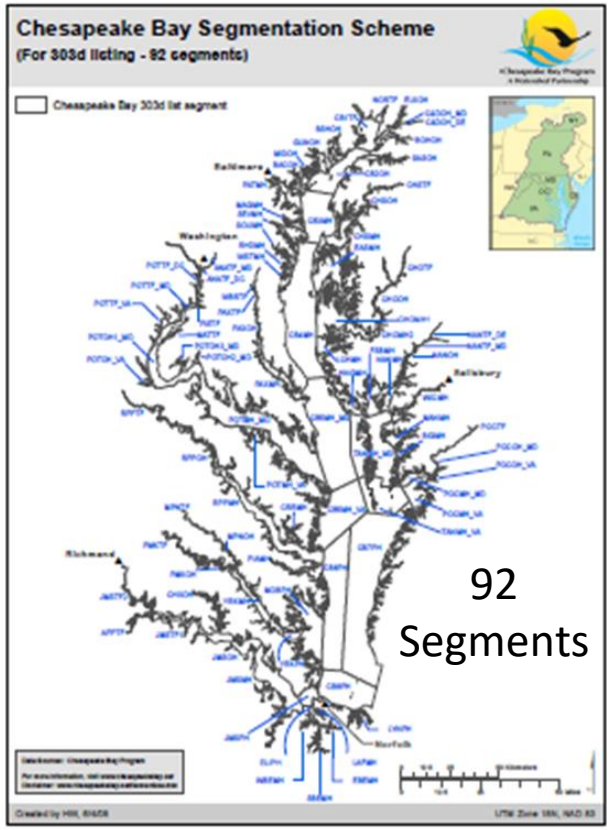
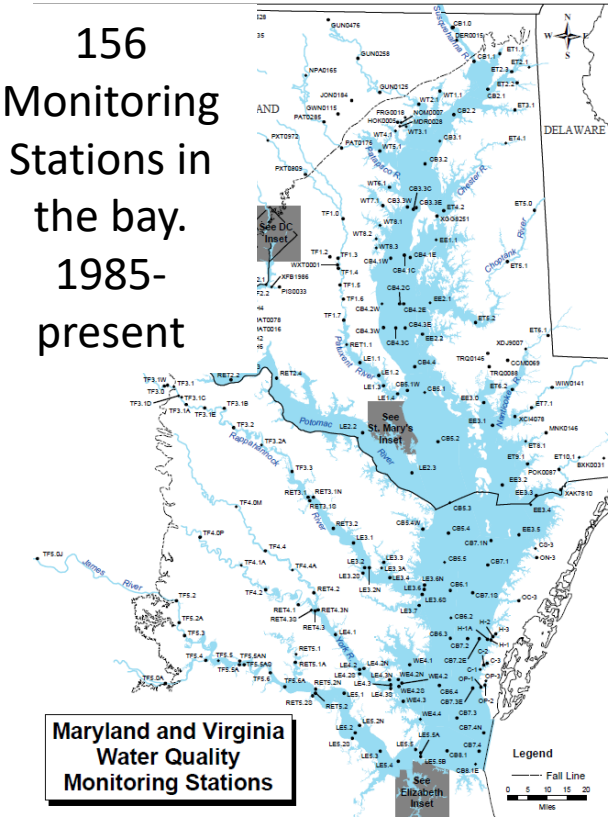
**Question:** How much of the bay do we have all the water quality data needed to report on its health status (i.e., its water quality standards for dissolved oxygen, bay grasses/water clarity and chlorophyll *a*)?



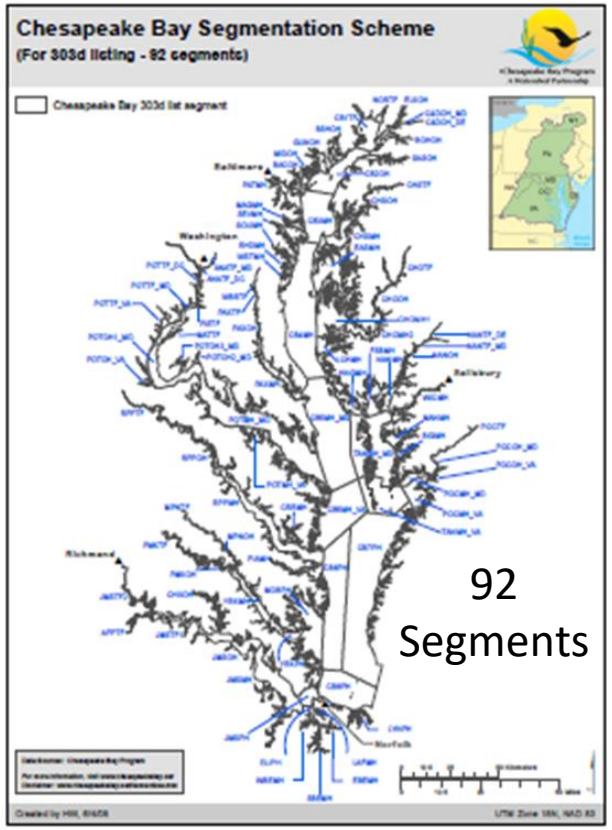

156 Monitoring Stations in the bay. 1985-present




Millions of data points…
Over $5 Million per year to collect the data

There are **92 segments in the tidal waters of the bay**. We have 156 monitoring stations operating since 1985.

**Question:** How much of the bay do we have all the water quality data needed to report on its health status (i.e., its water quality standards for dissolved oxygen, bay grasses/water clarity and chlorophyll a)?

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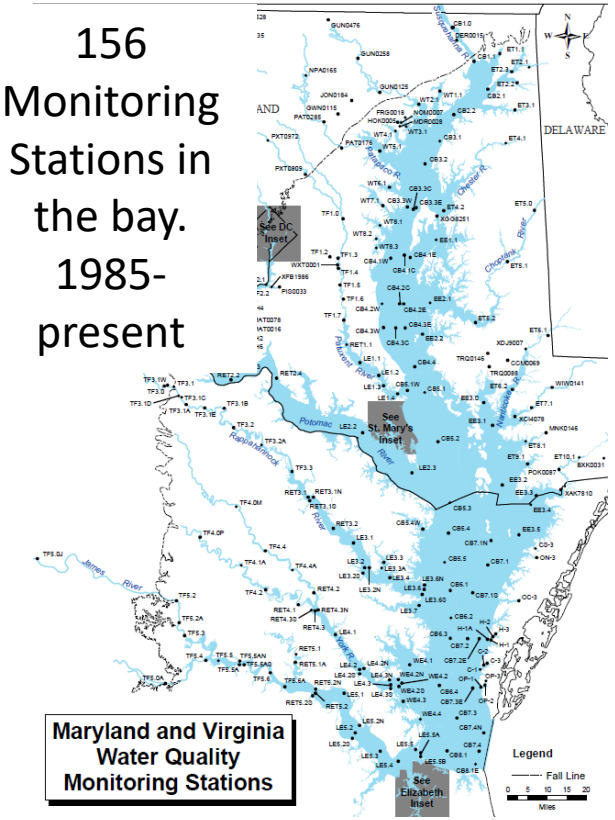
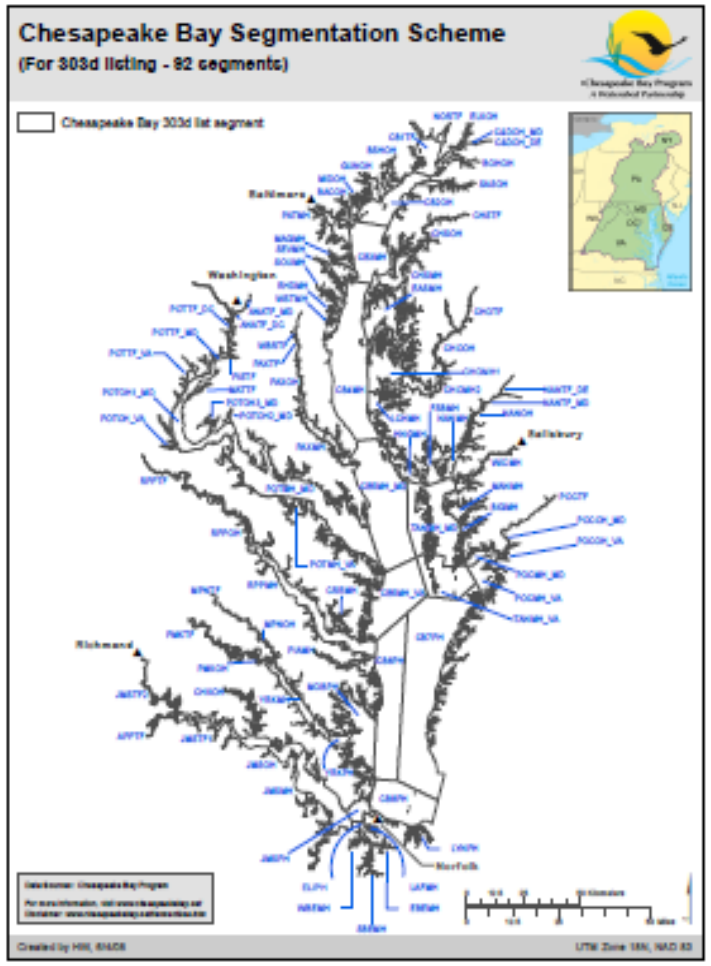
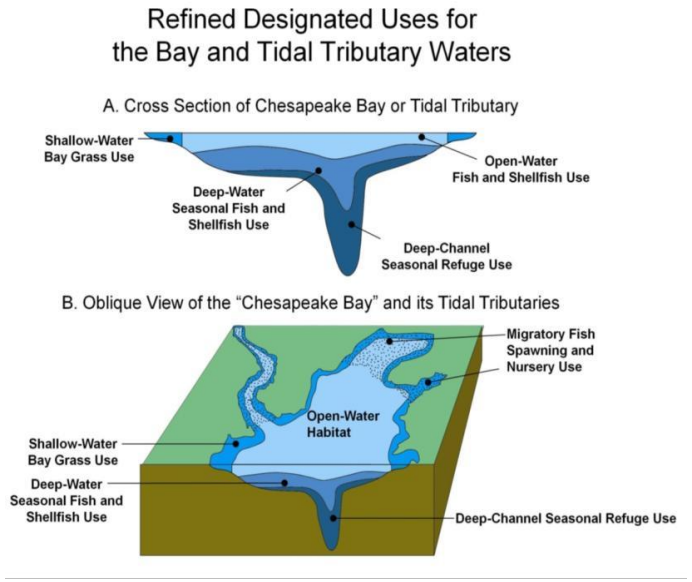



- **Answer is…**

# 0 segments

# Clean Water Act Water Quality Standards Monitoring and Assessment Issue: A segment must meet **all criteria** in **all applicable designated uses** for a decision on delisting in State water quality standards




*No assessment available for 61% (512 of 838) decisions needed*

(PT)

**0**

The number of segments we have full monitoring data accounting for to support all criteria assessments needed to make a delisting decision

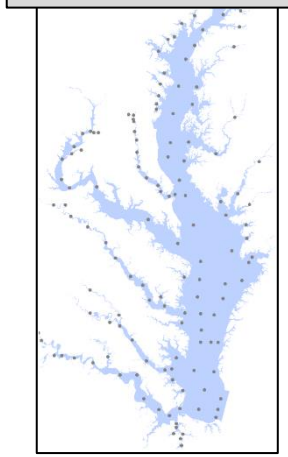
# What do we do?

- We can work our entire careers and report nothing.
  - We can collect the same data we are collecting at a cost of over $5 million/year in monitoring alone and report nothing about the bay because we don’t have all the data we need.

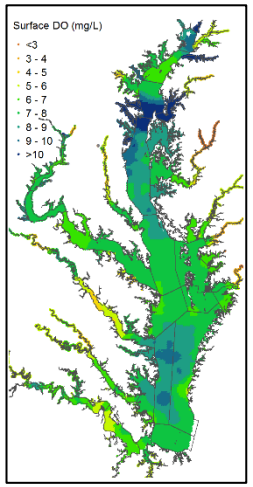
- Use a resource sensitive indicator to inform management and policy direction.
  - We can create an indicator to estimate conditions that fills in missing information with best estimates
  - This interim measure allows us to track progress until we get the data we need for full accounting.

# WQS Criterion Assessment

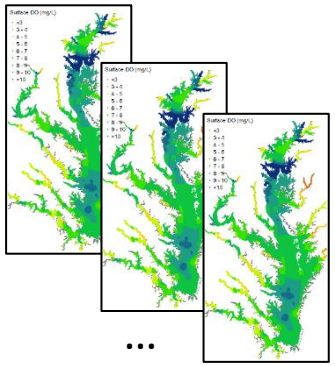
**1.** Collect bi-weekly to monthly data at each monitoring station



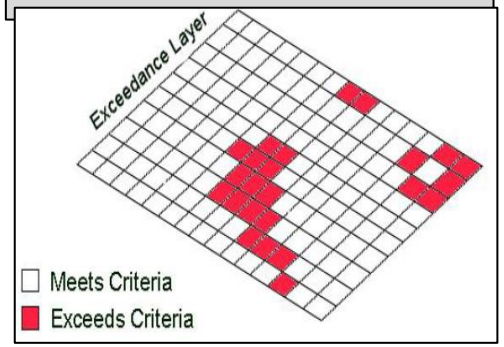
**2.** Convert the station DO data to Baywide values using the CBP interpolator



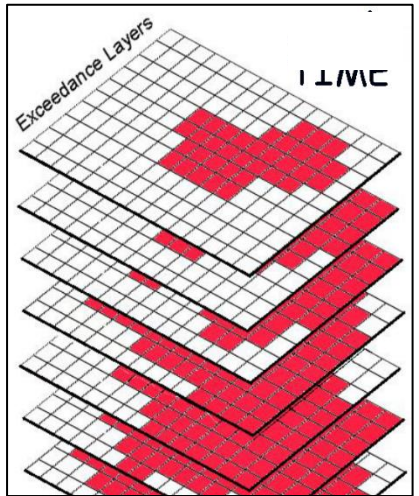

**3.** Combine interpolations for a season over the 3-year period



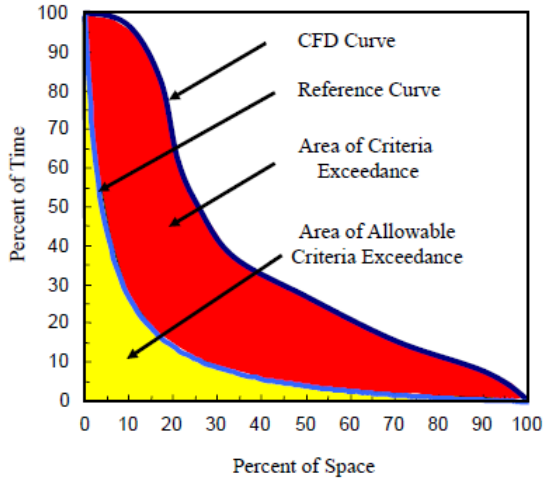
**4.** Compare the interpolated values with appropriate criterion values to compute the spatial extent of exceedance



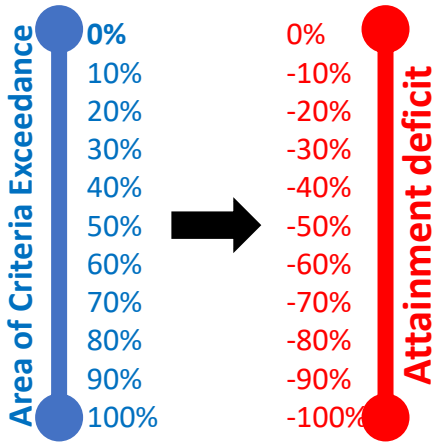

**5.** Repeat Step 4 for each sampling event in the 3-year period to determine the cells' extent of exceedance




**6.** Calculate the cumulative probability distribution (CFD) for extent of exceedance for all cells within each segment




**7.** Quantify attainment status (attaining or not) for the 3-year period



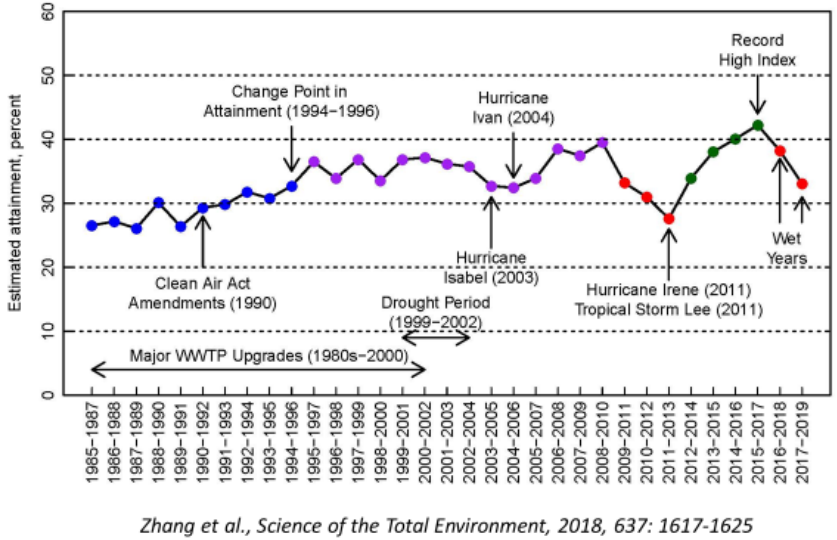
We developed and published a method to estimate the condition of the bay from the subset of data available (Hernandez et al. 2020)

We apply the method for managers and public to communicate our best estimate of change over time (Zhang et. al. 2018)

We apply the  indicator results in analyses to understand significant drivers of water quality behavior (Zhang et al. 2020, Zhang et al. 2021)

Hernandez, Tango and Batiuk 2020.

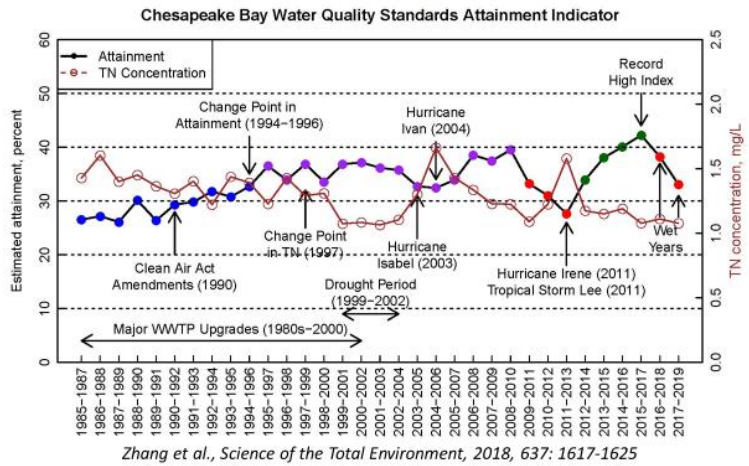
## Chesapeake Bay WQS Attainment Indicator (1985-2019)




*Zhang et al., Science of the Total Environment, 2018, 637: 1617-1625*

Zhang et al. 2018

## Effect of Nitrogen Input

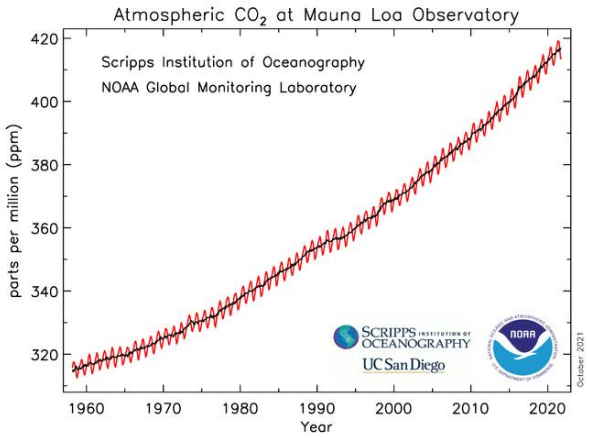



*Zhang et al., Science of the Total Environment, 2018, 637: 1617-1625*

Zhang et al. 2018

** The indicator is NOT a report out on the actual achievement of water quality standards.*

# In summary: Indicators are resource sensitive yet powerful information tools.

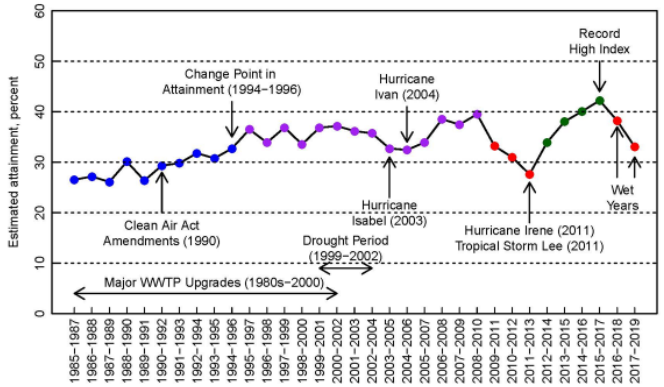



Aim for balance – don't let the perfect be the enemy of the good

- As an indicator, the data informs us about:
  - Status
  - Trends
  - Points us toward management options
  - Points us to policy considerations
  - Reflects science-based

- This indicator is not
  - A complete global accounting of our parameter of interest – that is a census.
  - A complete accounting of everything we could be measuring

Chesapeake Bay WQS Attainment Indicator (1985-2019)




*Zhang et al., Science of the Total Environment, 2018, 637: 1617-1625*

# Discussion

- Does this give you any ideas about your own indicator development?

- Do you see an opportunity to resize and reshape your vision for developing or evolving an indicator?

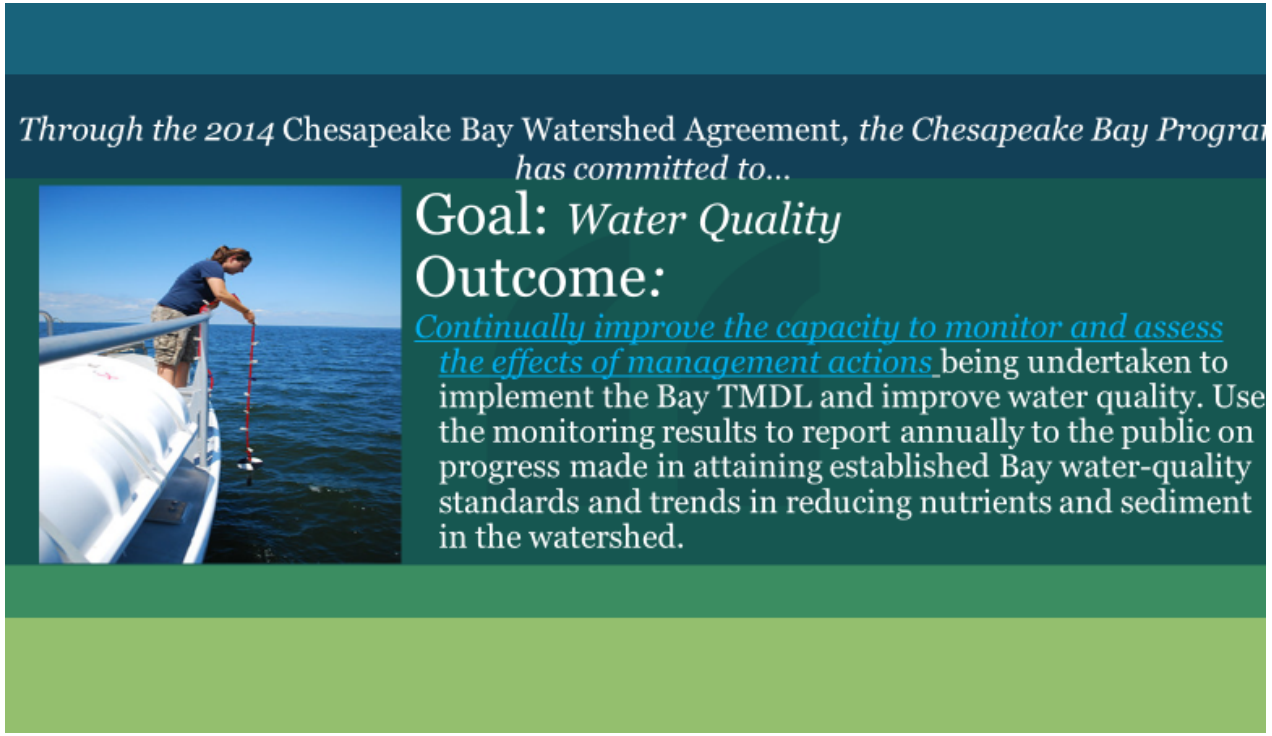
- Does this help your vision for how much monitoring you may need and resources you may need to get management and policy-relevant information in a timely manner?

# You can’t change what you don’t measure:
# Translating qualitative statements into quantitative measures.

# Water Quality Standards Attainment and Monitoring Outcome – Potential Translations

- Our outcome wants us to "continually improve the capacity to monitor and assess the effects of management actions".

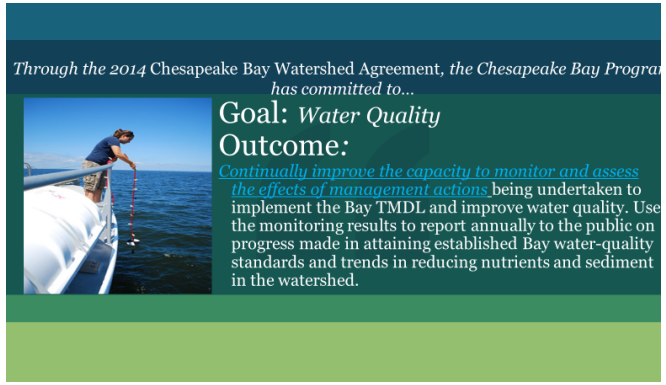
- We do not have a published metric or indicator of capacity.

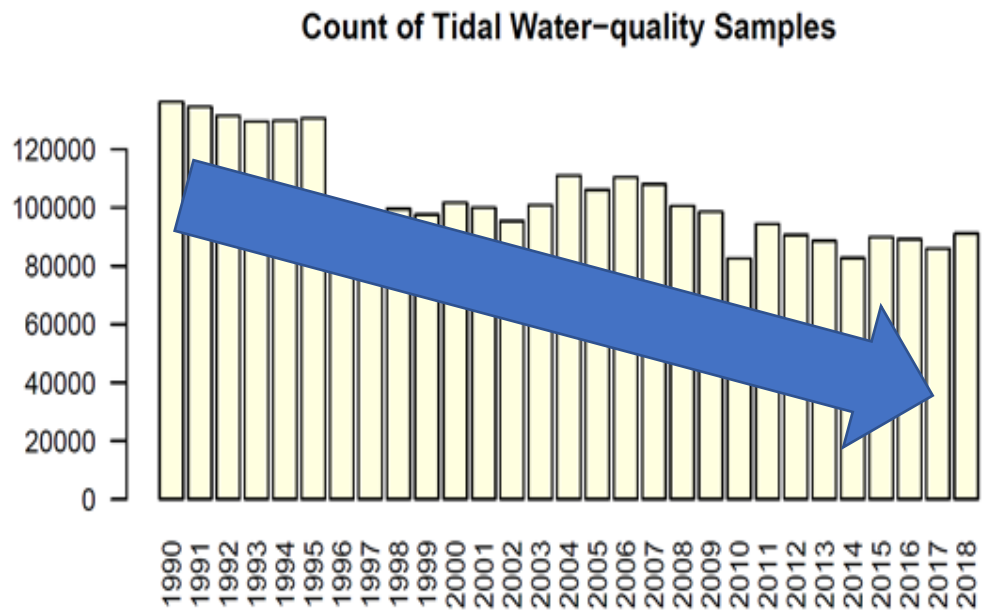


# Water Quality Standards Attainment and Monitoring Outcome – Potential Translations

- Capacity – one metric is binary. Are we assessing the water quality standards or not? The answer is NOT. (Translation – we are below capacity)
  - Powerful message. Very little sense of progress with binary measures to understand if we are improving.

- A potential metric we could provide to show capacity status and trends is samples collected per year. It is declining.



# Another hypothetical example: Let's look at the Sustainable Schools Outcome

- ***Continually increase the number of schools in the region*** that reduce the impact of their buildings and grounds on their local watershed, environment and human health through best practices, including student-led protection and restoration projects.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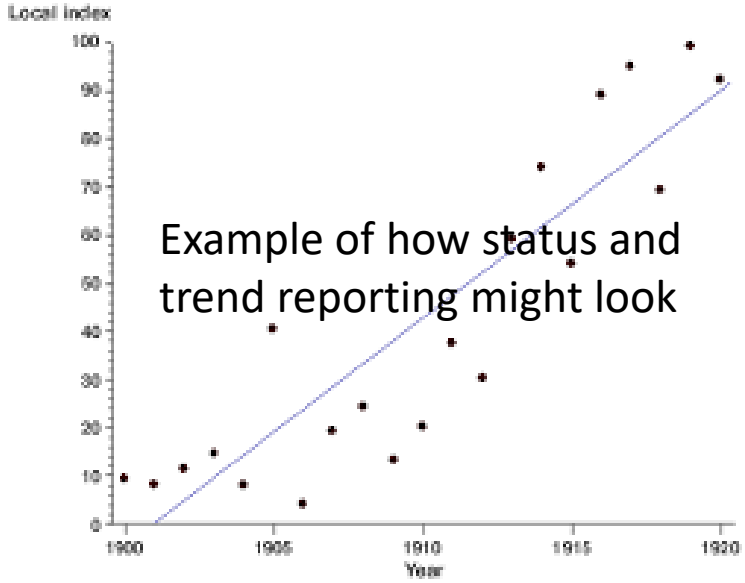
- A translation for a target is to address the phrase CONTINUALLY INCREASE,
- TRANSLATION: That means show that you are **maintaining a positive trend until you have no more schools to work with.**
  - **An implicit target is have 100% of schools in the region** to be sustainable schools.
- We **do not need data on every school every year**. We can subsample the school systems and estimate status, assess progress over time.
  - This also means you need to think about data collection. You can use sampling statistics.




Example of how status and trend reporting might look

# Another hypothetical example: The Student Understanding Outcome

- "**Continually increase students' age-appropriate understanding of the watershed through… (etc. etc. etc. methods**, MWEEs)."
- Translation: One translation here is to show that for every cohort, you can show that they collectively demonstrate improved understanding of the watershed.




| Cohort start | 5th grade avg test score | 9th grade avg test score | 12th grade avg test score | Continually increase cohort? |
|---|---|---|---|---|
| 2000 | 68 | 72 | 81 | Yes ↑ |
| 2001 | 70 | 73 | 86 | Yes ↑ |
| 2002 | 69 | 68 | 67 | No ↔ |
| … | | | | |
| 2020 | 73 | 78 | 87 | Yes ↑ |

# Maintain Healthy Watersheds – another way to consider assessing a complex outcome

- Maintain 100% of healthy watersheds.
- Translation of a "healthy watershed" **= if any 1 measure falls below a healthy threshold** – because everything (100%) must be healthy - **then the goal is failed. It is all or nothing.**

- Here you go, your work is done -
  - MD Brook trout Assessment:
    - "**The most recent information on our brook trout populations can be found in our Five year (2014-2018) statewide survey.**
      - ***We document an apparent loss of 27% statewide, with almost a 50% loss in our central region.***"
    - Reminder that the brook trout goal is to increase populations by 8% in the watershed.


- Because of the way the Goal and Outcome is worded – 100% healthy watershed stay healthy - then taking a tact where simply showing 1 parameter of health is out of compliance allows you to accurately say your goal will not be met in 2025 or anytime soon.

# In summary, remember…

| REMINDER: Important Indicator Qualities |
| --- |
| **Simple and easy to understand** |
| Be scientifically well-founded |
| Have a reference or threshold value of significance |
| Be responsive to changes in the environment |
| Show trends over time |
| **Feasible to measure and report (reasonable cost/benefit ratio)** |
| **Updated regularly with reliable procedures (timely with support of a monitoring program)** |
| Adequately documented, known quality |
| Be useable by the community |
| Policy relevant |

## Complementary thinking:

- Understand AND EXPLAIN
- Grounded in our understanding
- Meaningful measure
- Show management relevance
- Show responsiveness over time
- AFFORDABLE
- Committed resources in place
- Document method
- Useful
- What can we do about it?

# Discussion

- Do these examples give you any ideas about the feasibility of translating your qualitative outcome language to target one or more quantitative measures of status and progress? Yes or no and why?

- Can you envision a target measure and how you would collect data to address it, or how you could use an existing data collection to address it?
  - You don’t have to create a new monitoring program, you can borrow existing work and shape it to your needs, e.g., is there a national assessment that you can cookie cut out the Chesapeake Bay watershed data as we do with some of the Climate Resiliency Indicators?