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Nutrient Limitation in Chesapeake Bay: Analysis of long-term monitoring data & implications for water-quality management

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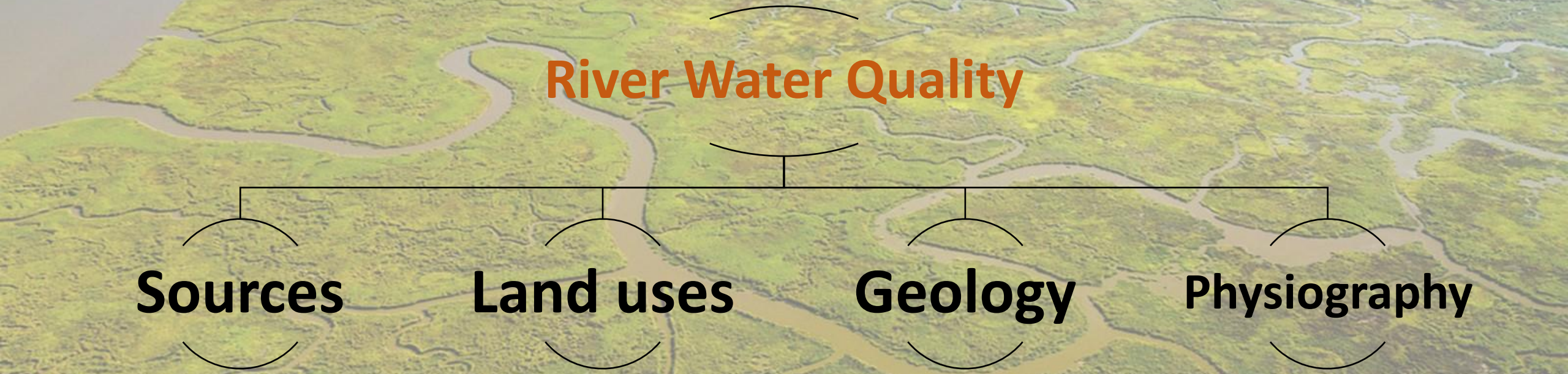
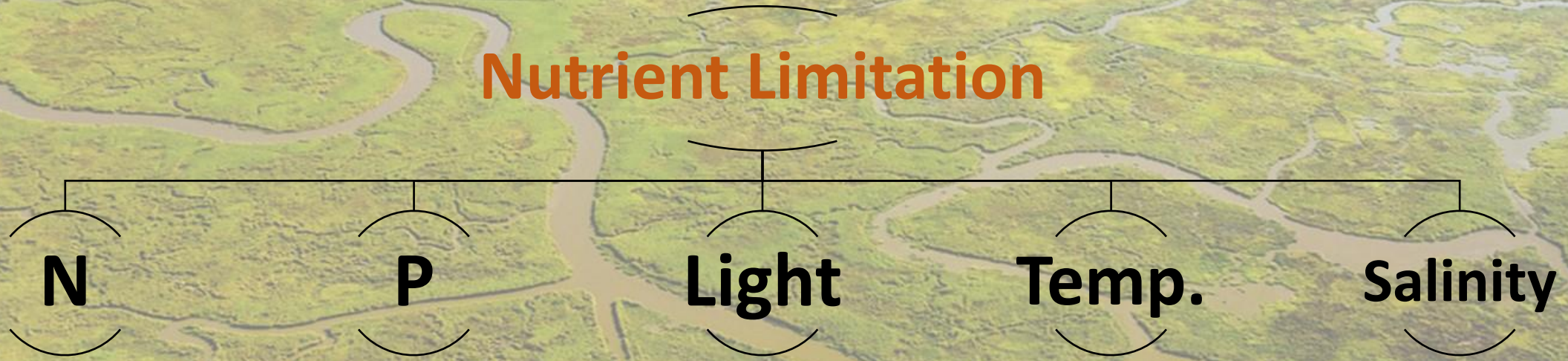
A watershed example: Synthesis and analysis of monitoring data from the Partnership to understand regional patterns and drivers of water-quality (e.g., nitrogen) trends.

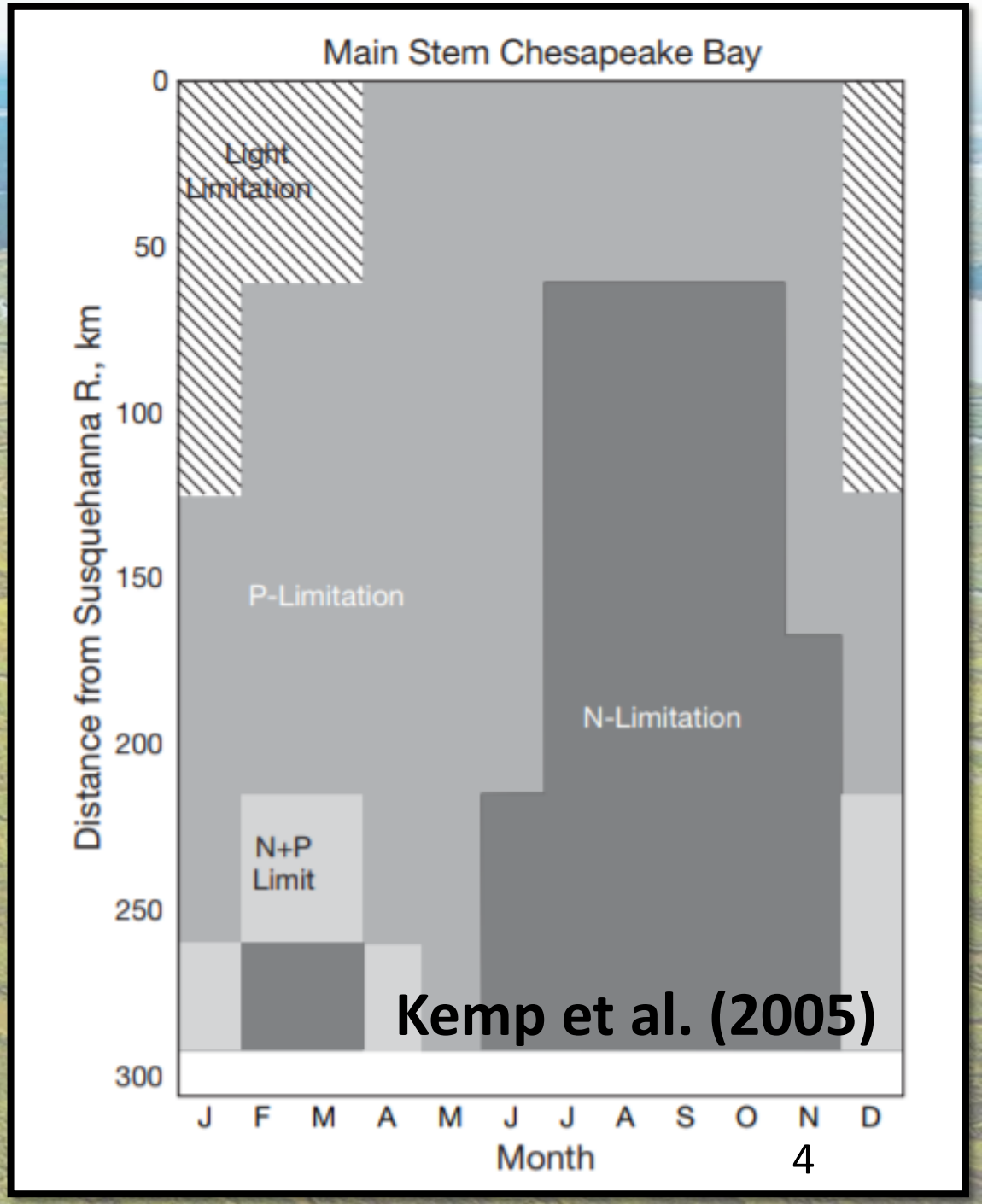


An estuary example: Synthesis and analysis of monitoring data from the Partnership to understand patterns of and changes in nutrient limitation to algal growth.



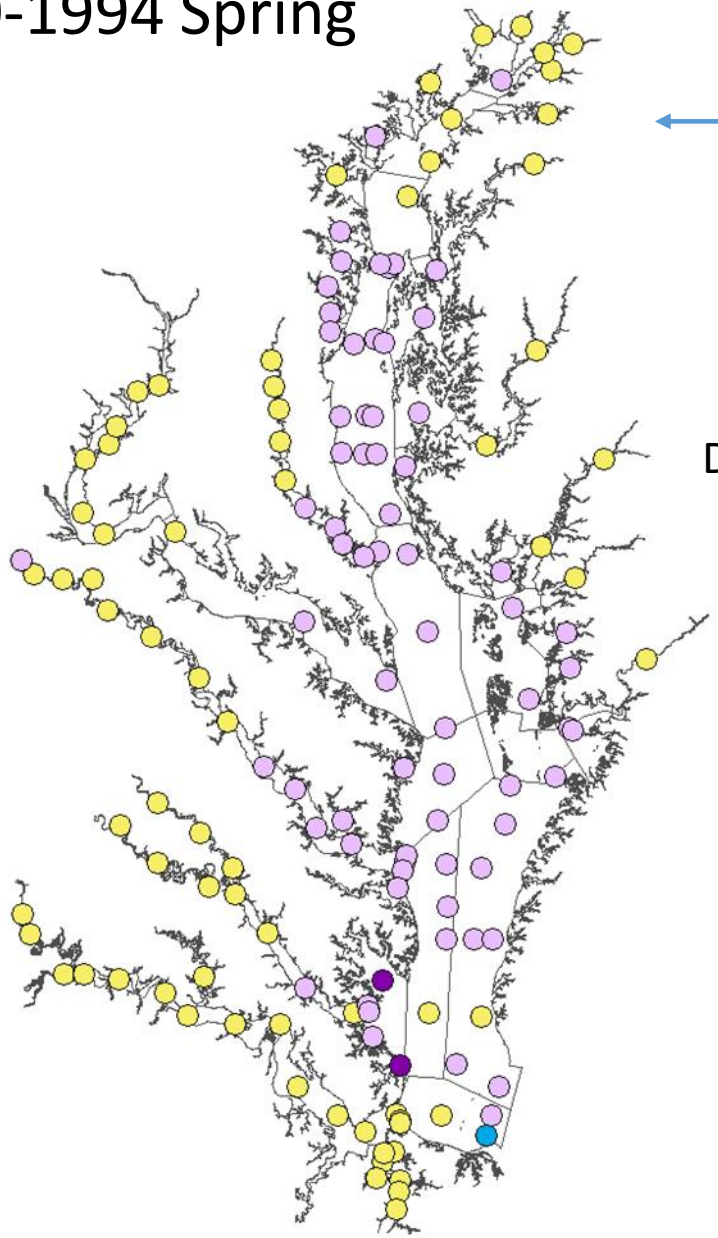
Why does it matter?

Nutrient limitation has shown large spatial and seasonal variations in Chesapeake Bay, which have implications to nutrient reductions (Fisher et al. 1999, Kemp et al., 2005).



Recent signs of change from tidal water-quality data

1990-1994 Spring



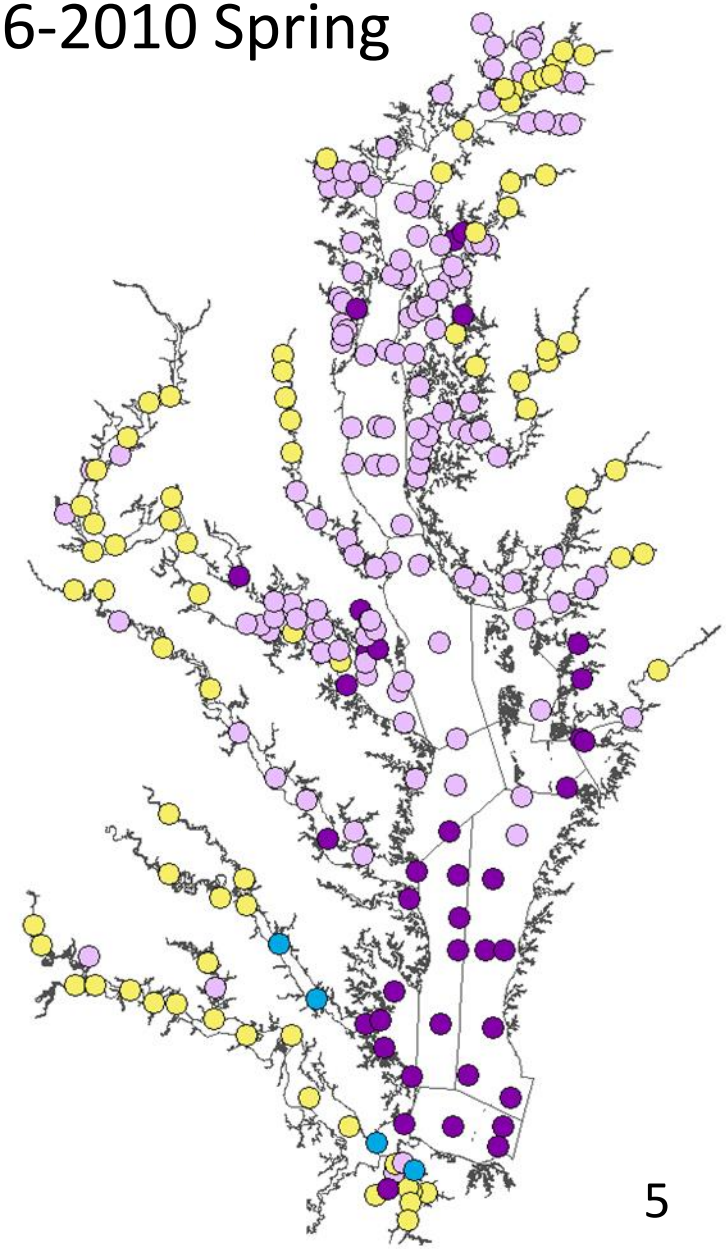
Similar flow periods

Neither	Light
DIN/0.07 < 1	Nitrogen
DIP/0.007 < 1	Phosphorus
Both	Nitrogen & Phosphorus

Percent of samples

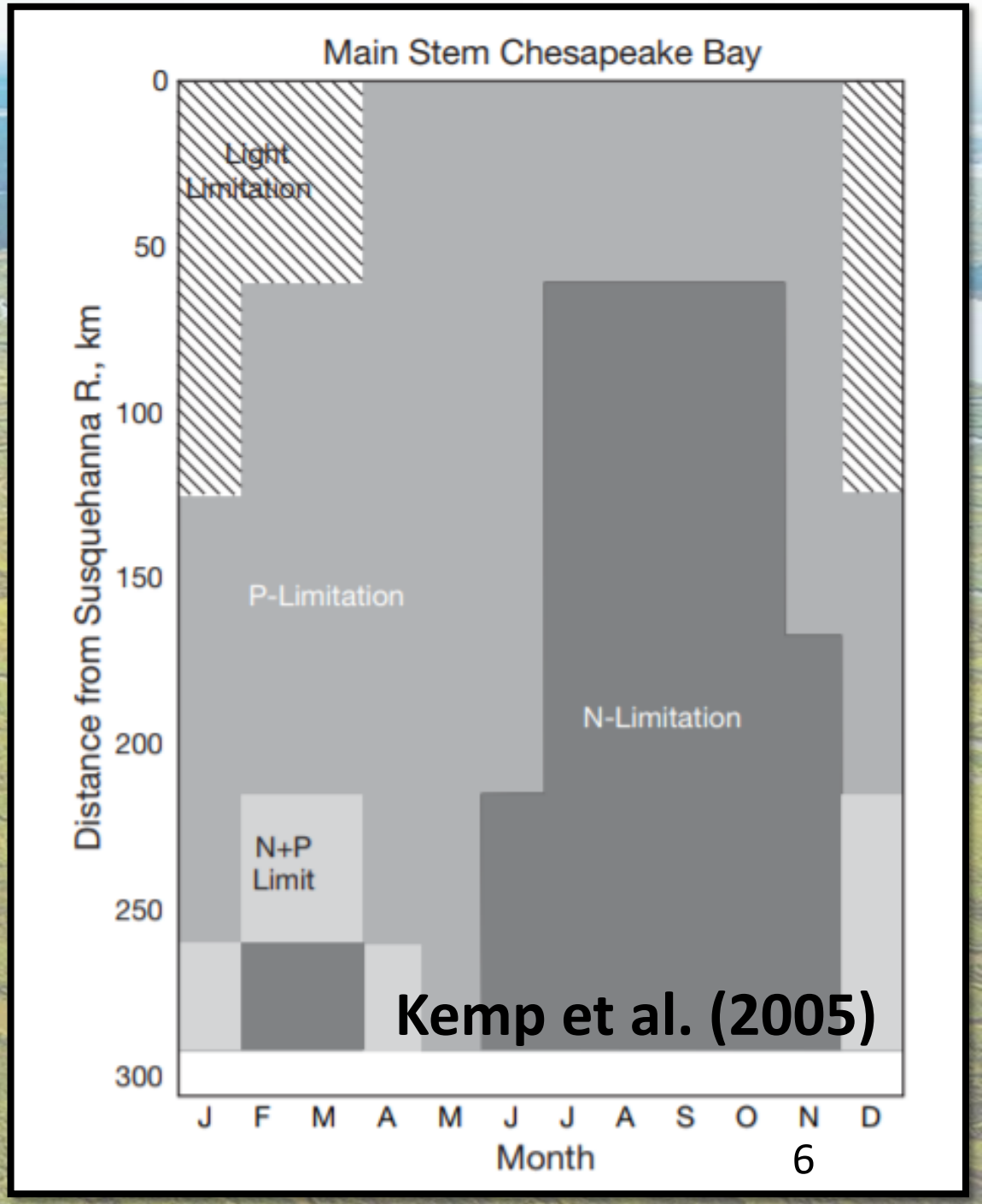
50%	Light	31%
0.7%	N	1.5%
48%	P	52%
1.4%	N&P	16%

2006-2010 Spring



Hypothesis

Given the long-term efforts to reduce nutrients to the Bay and different trends in N and P loads, nutrient limitation patterns in the mainstem may have changed temporally and spatially.



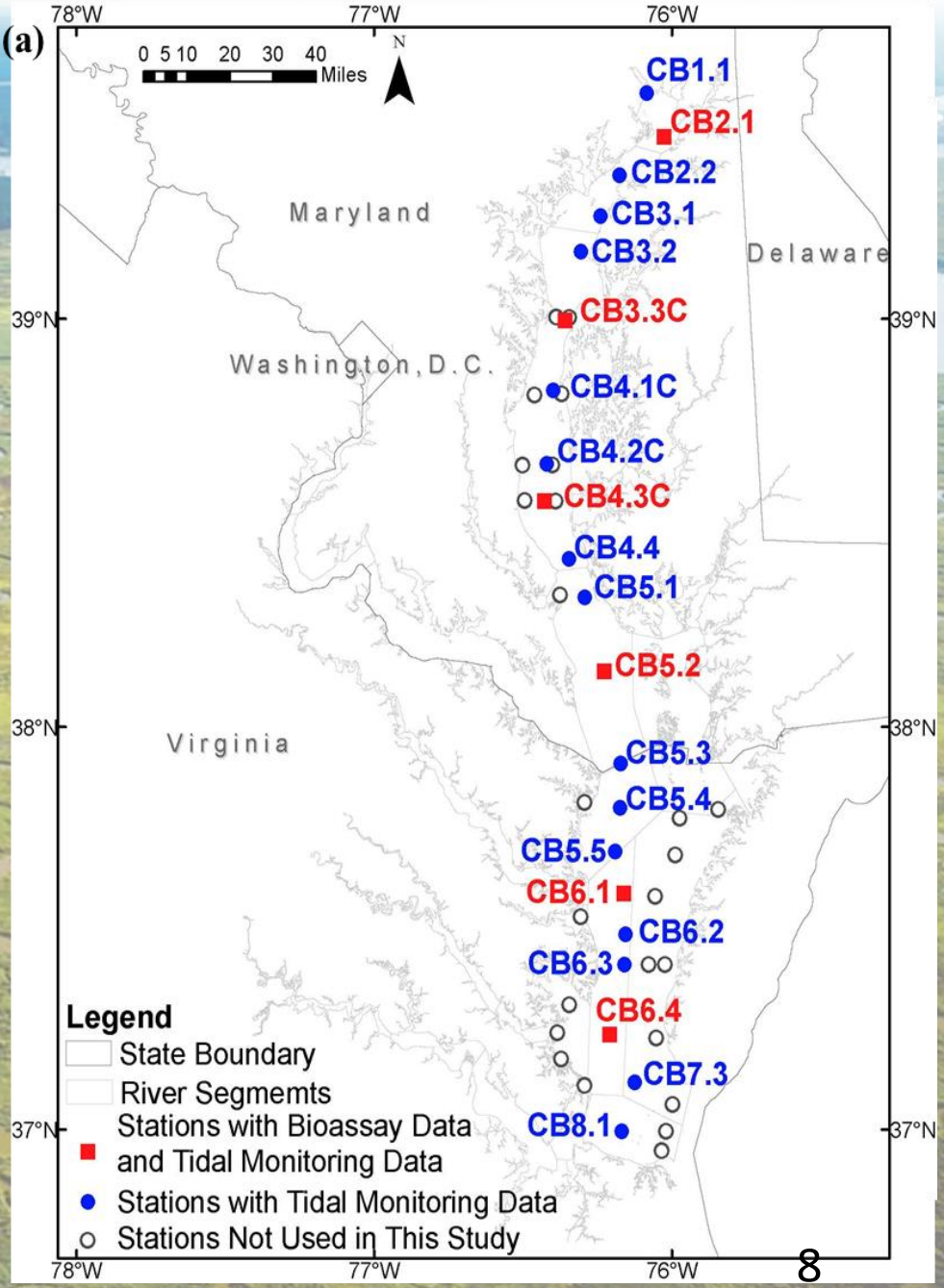
Data of Bioassays for Nutrient Limitation

1985	1986	1987	1988	1989
1990	1991	1992	1993	1994
1995	1996	1997	1998	1999
2000	2001	2002	2003	2004
2005	2006	2007	2008	2009
2010	2011	2012	2013	2014
2015	2016	2017	2018	2019

Data of Tidal Water-quality Monitoring

1985	1986	1987	1988	1989
1990	1991	1992	1993	1994
1995	1996	1997	1998	1999
2000	2001	2002	2003	2004
2005	2006	2007	2008	2009
2010	2011	2012	2013	2014
2015	2016	2017	2018	2019

Goal 1: To develop empirical approaches to relate tidal monitoring data to bioassay-based nutrient limitation ("truth") in the concurrent period of 1992-2002*

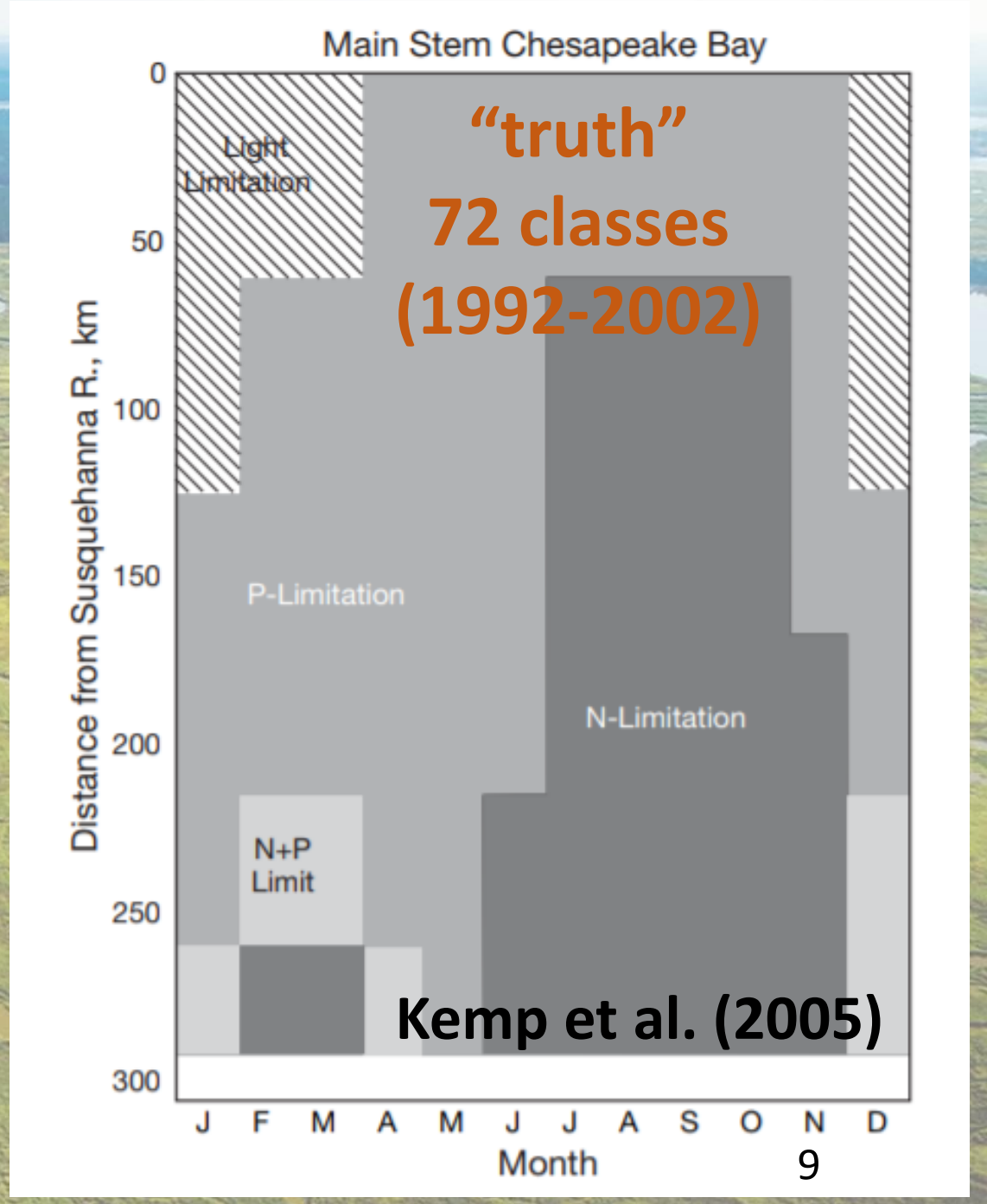


* Zhang, Fisher, et al. (2021), Water Research, 188:116407, https://doi.org/10.1016/j.watres.2020.116407.

Data of Bioassays for Nutrient Limitation in 1992-2002

11 years of samples (n = 800+) at 6 mainstem stations

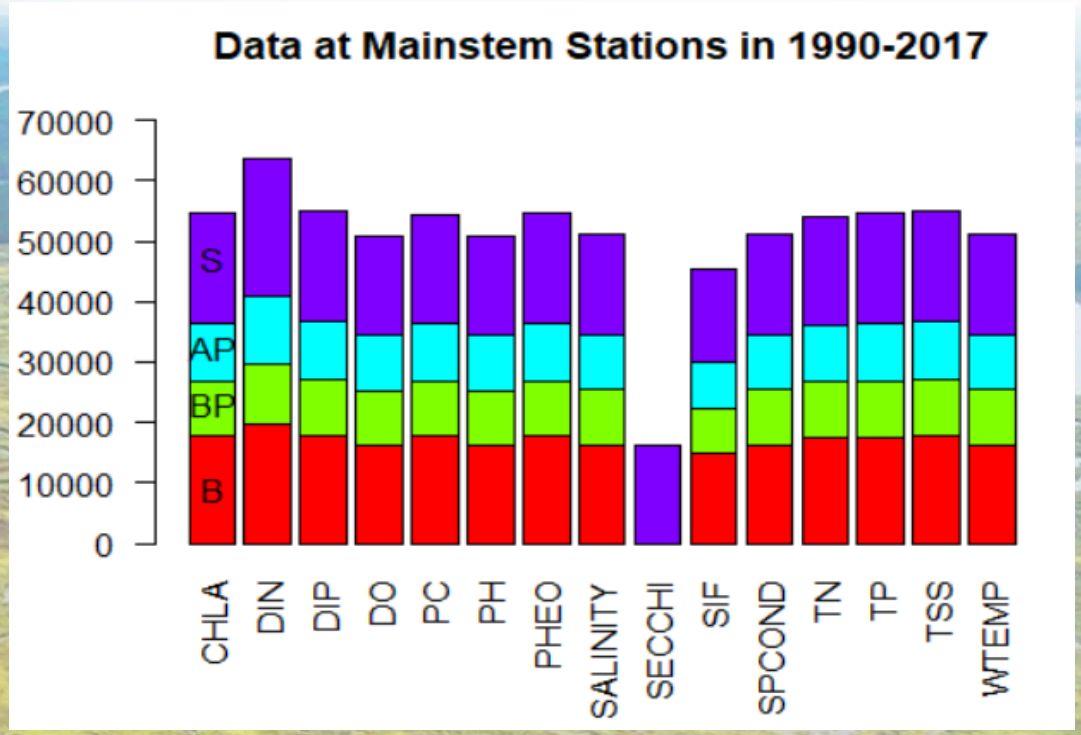
Data aggregated to 72 nutrient limitation classes (6 stations x 12 months)

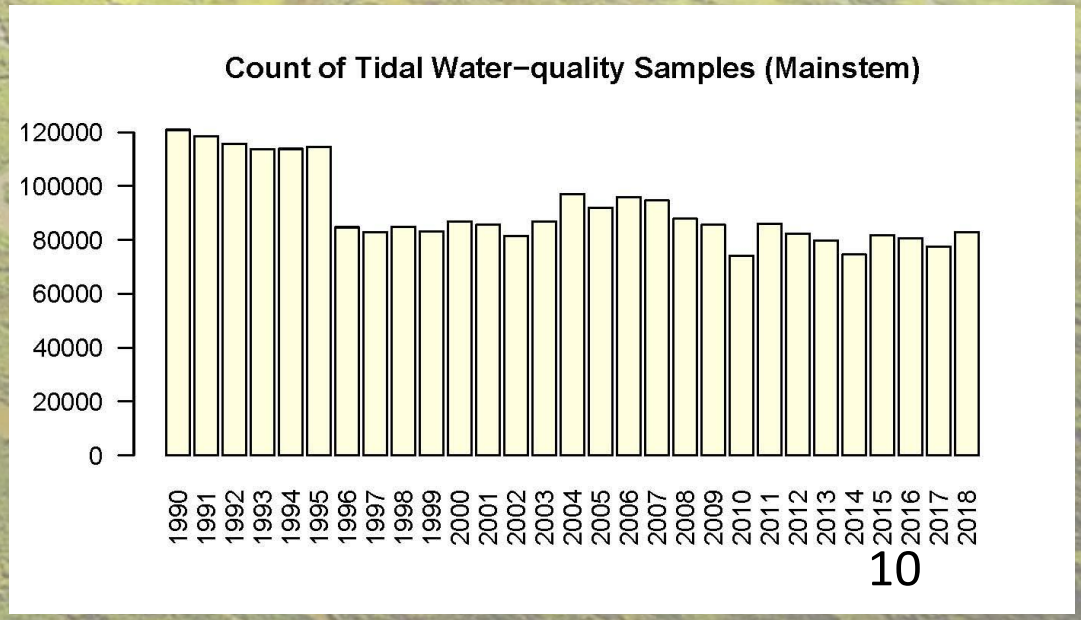


Data of Tidal Water-quality Monitoring in 1990-2018

Three decades of WQ samples at 21 mainstem stations

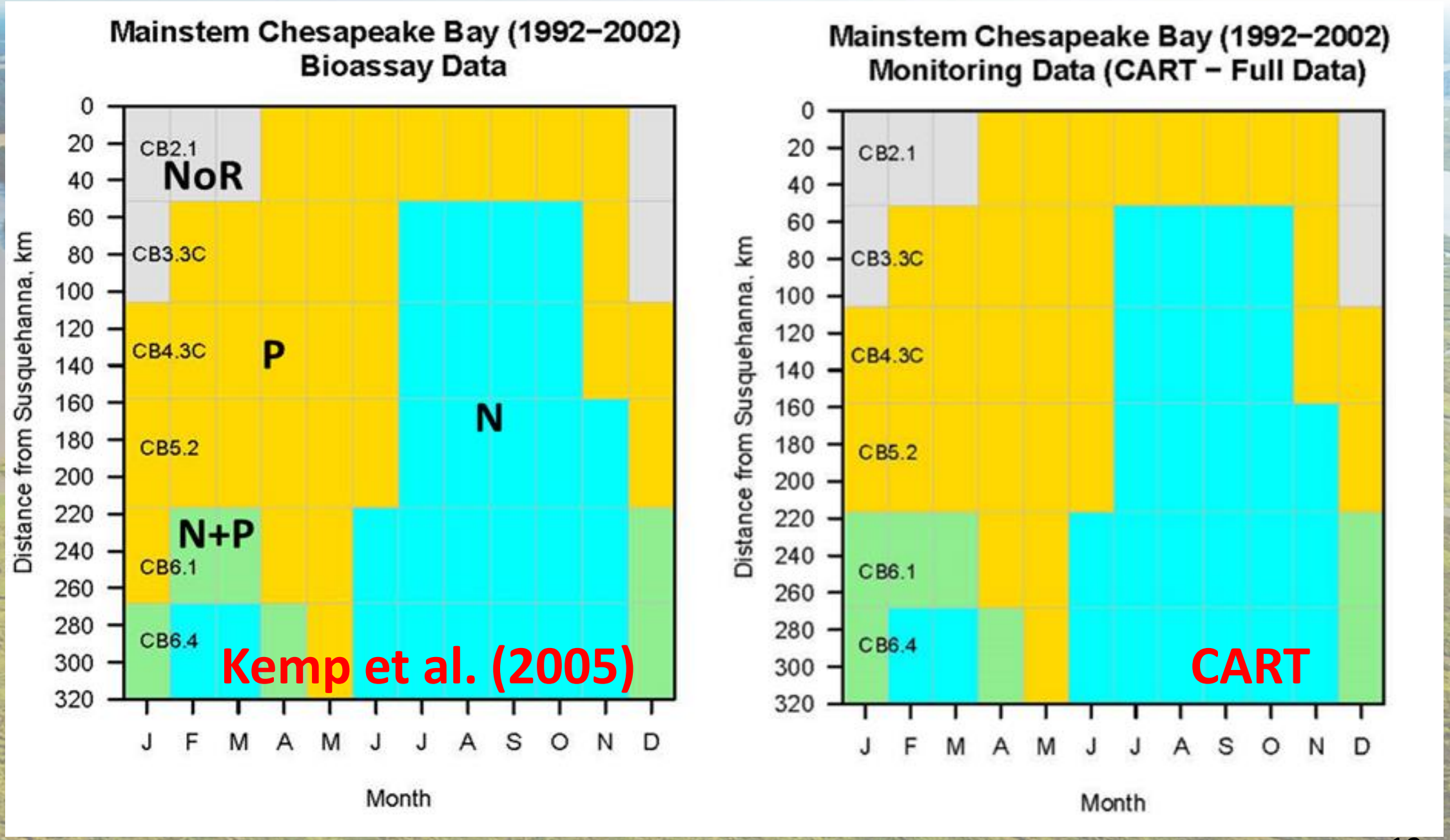
1992-2002 data aggregated to the size of bioassay classes (6 stations x 12 months)





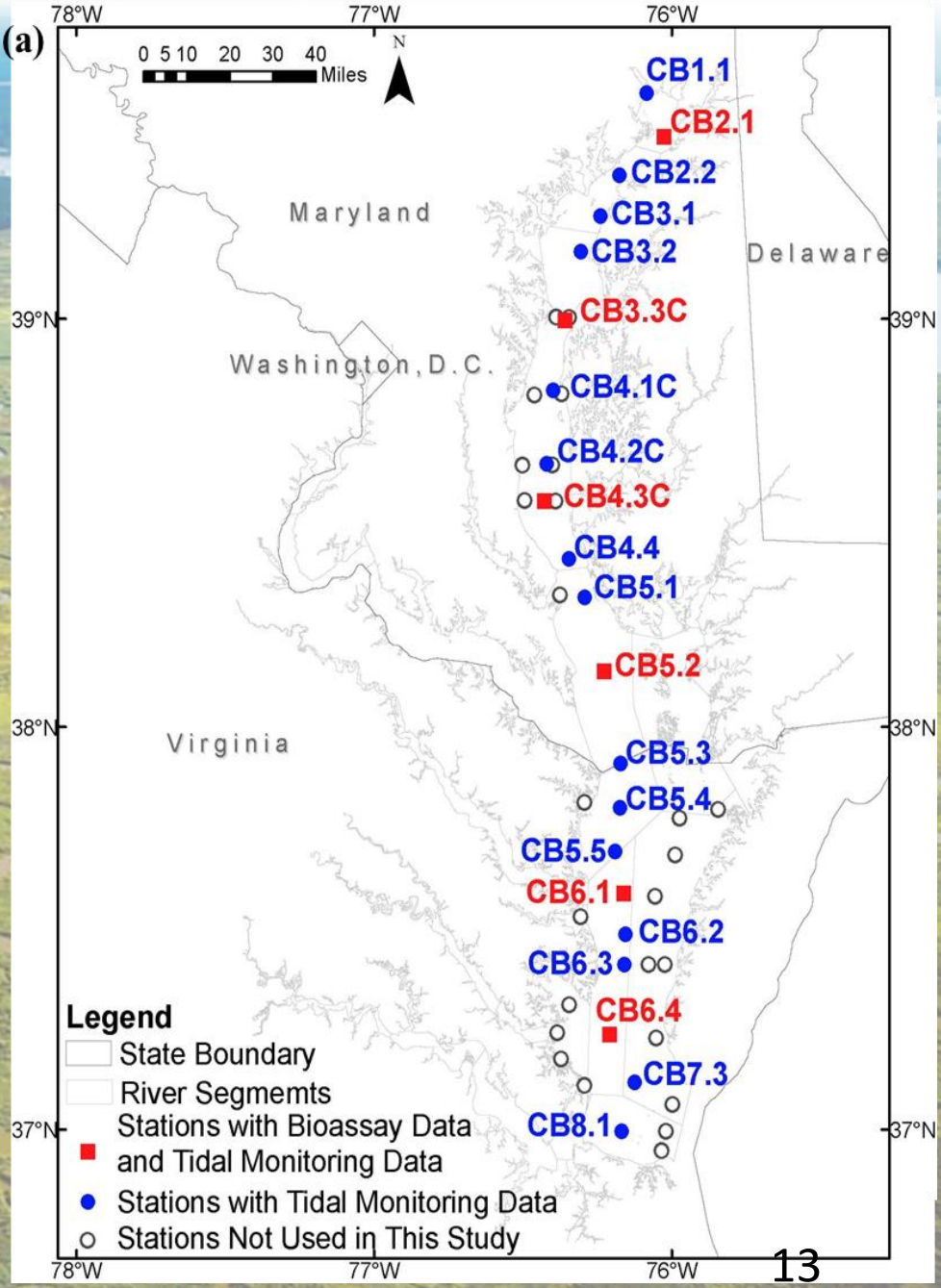
Three empirical approaches were evaluated, and CART satisfactorily reproduced the bioassay-based classes

Approach	Variables	Decision Rules	Classification Rate
A1. Probability-based approach	DIN and DIP concentrations	N (low DIN ≥ 50%) P (low DIP ≥ 50%) NP (both ≥ 40%) NoR (else)	43% (31 matches / 72)
A2. Nutrient index-based approach	DIN and DIP indices (based on concentrations)	N (N-index ≥ 0.5) P (P-index ≥ 0.5) NP (both ≥ 0.4) NoR (else)	57% (41 matches / 72)
A3. Classification and Regression Trees (CART)	DIN, DIP, + more (e.g., WTEMP, N:P ratio, CHLA, Secchi, Salinity)	Data-driven (through CART)	89% (64/72; LOOCV); 99% (71/72; Full Data)



NoR: No responses to nutrient additions

Goal 2: To apply the selected approach to monitoring data in more recent periods to predict nutrient limitation and explore potential changes in response to altered nutrient loading.*



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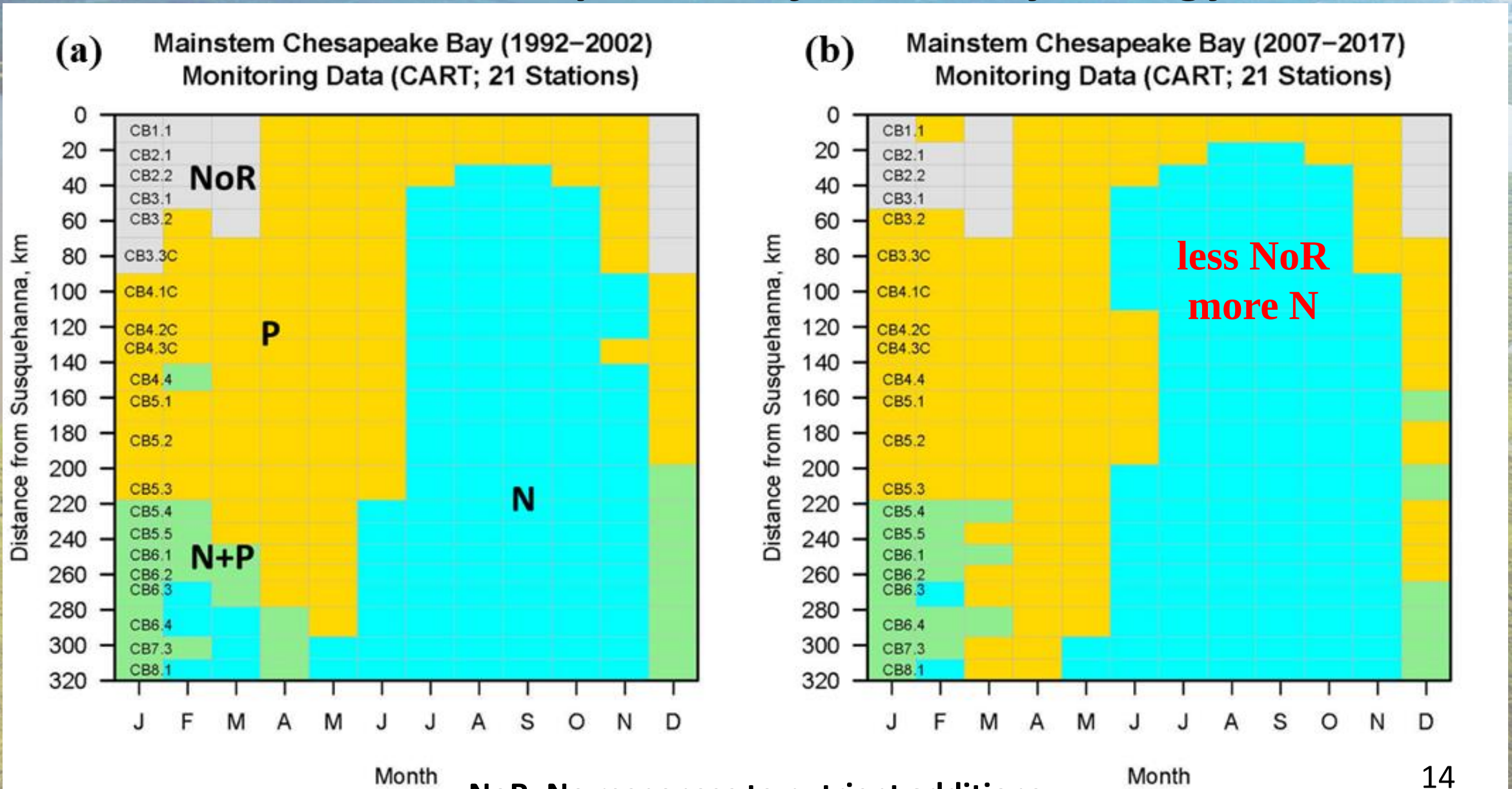
Changes in estimated nutrient limitation between two decadal periods of similar hydrology



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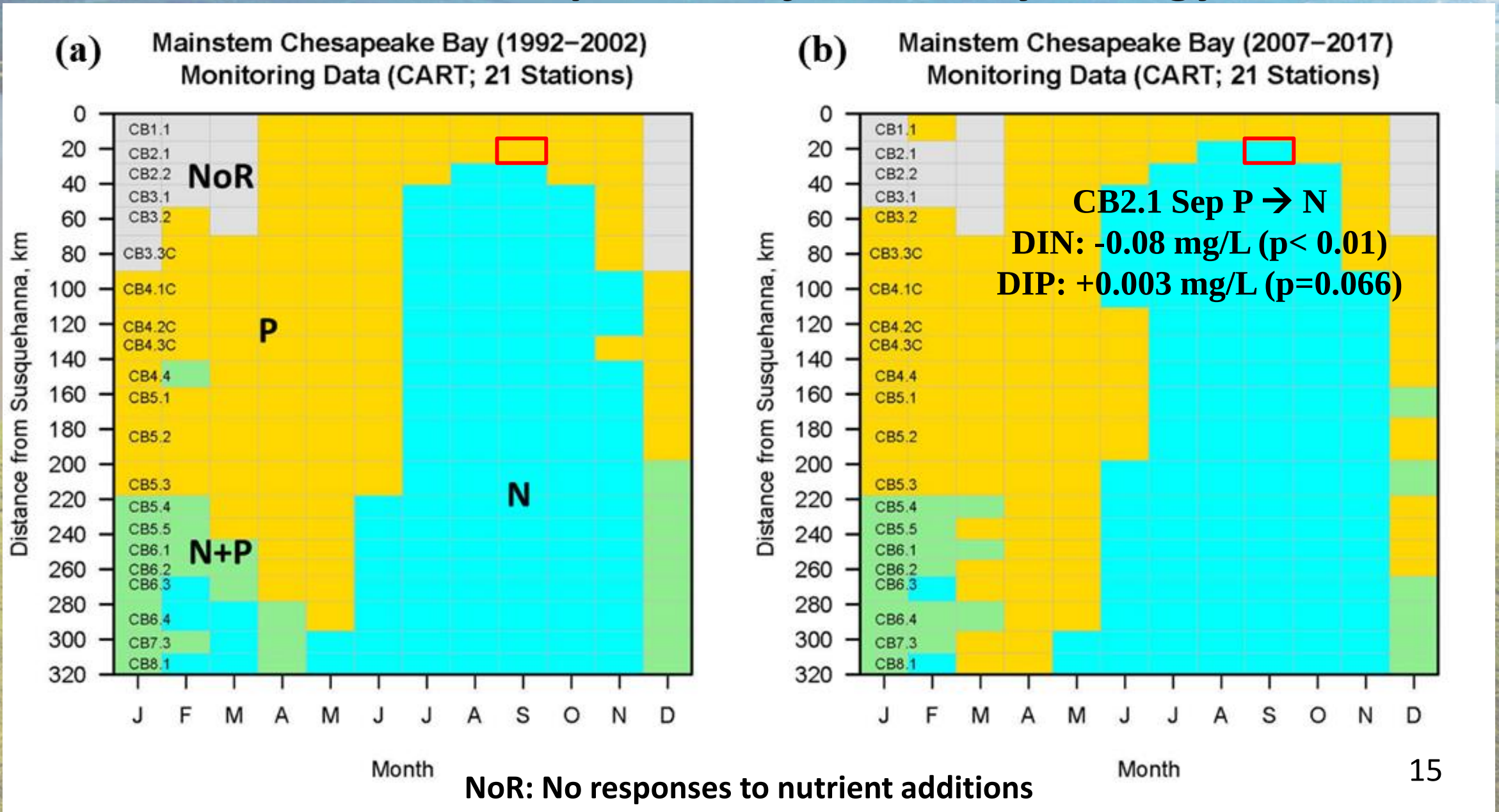
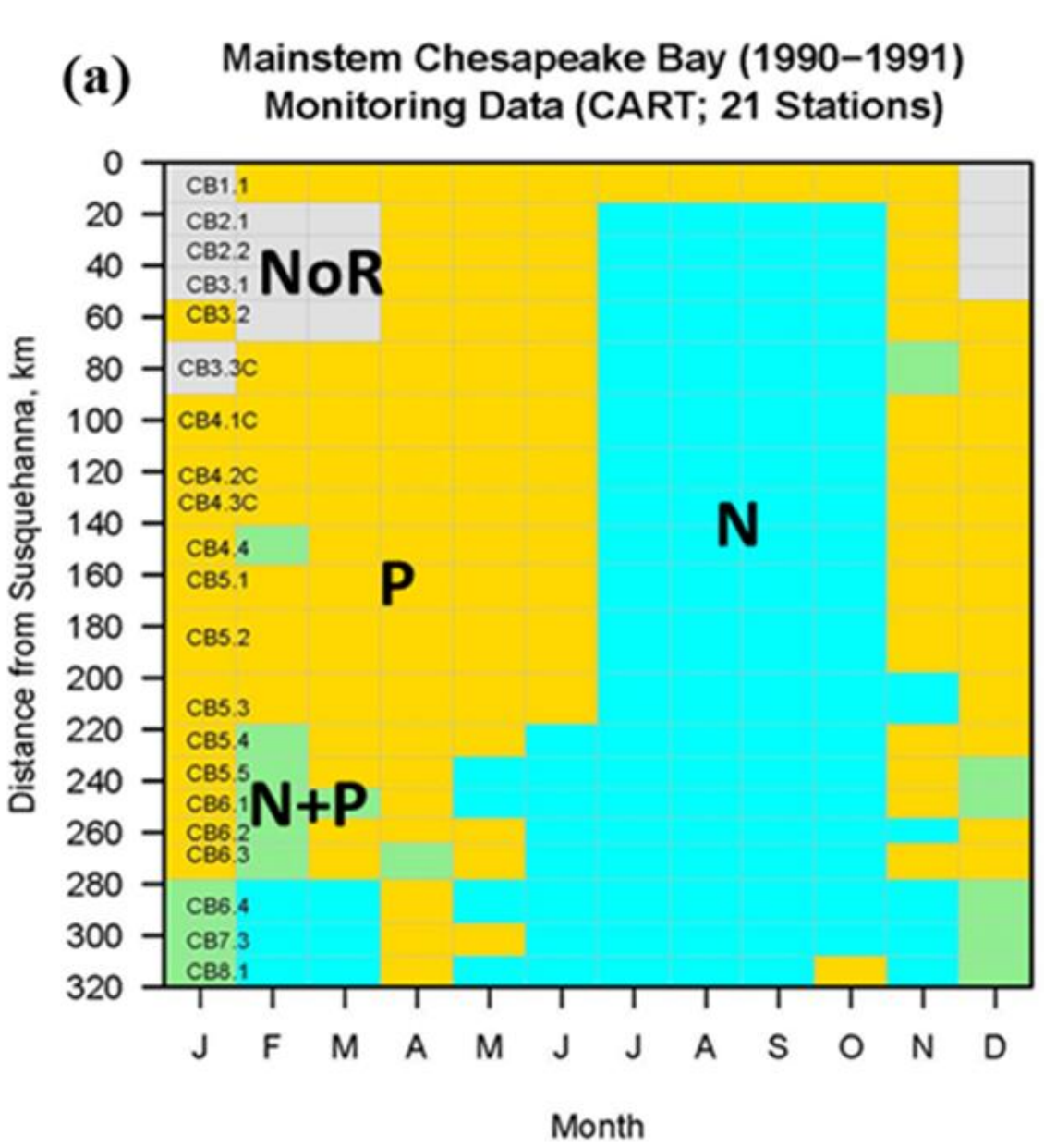
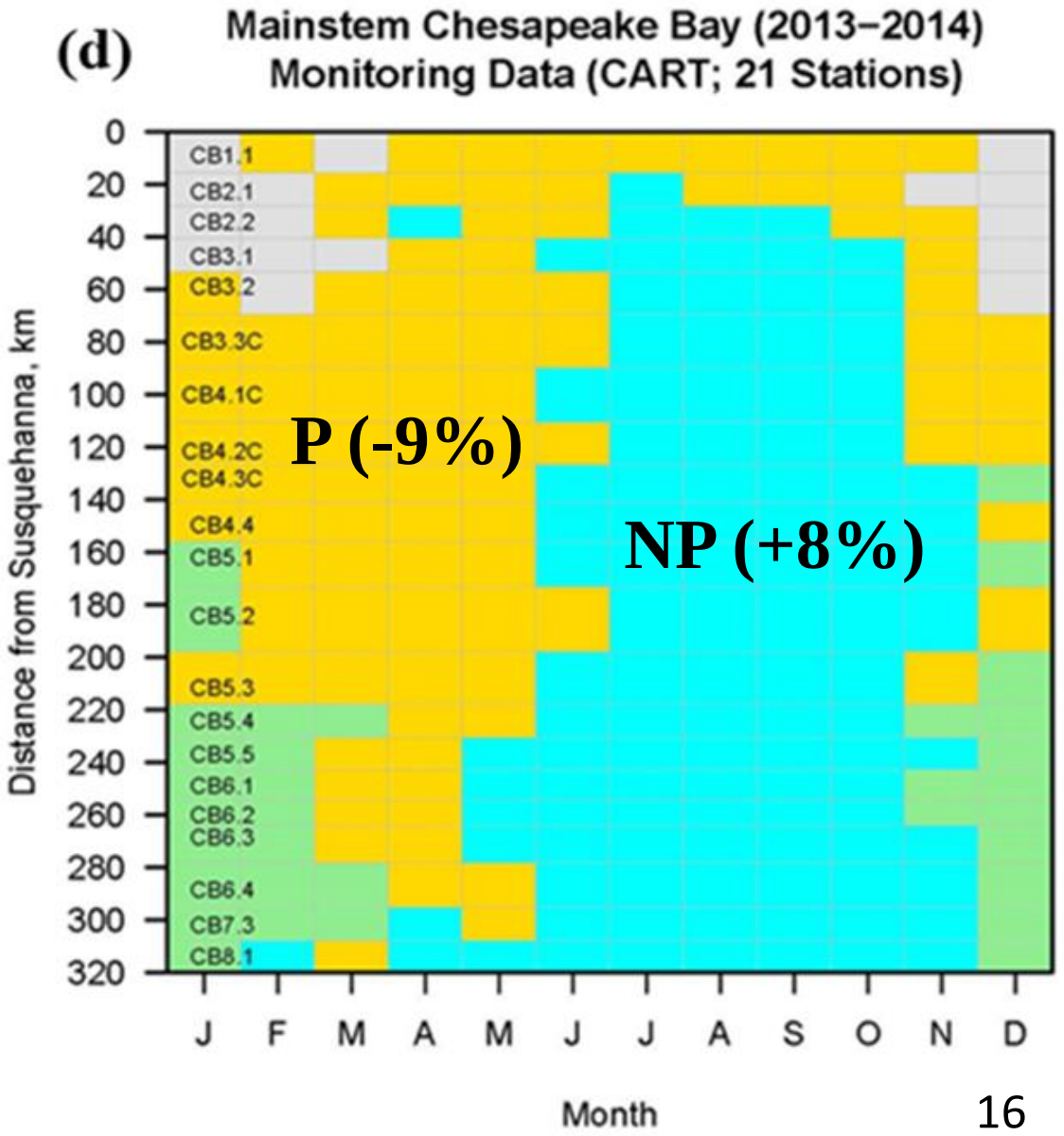


NoR: No responses to nutrient additions

Changes in estimated nutrient limitation between two 2-yr periods of similar hydrology





Key Messages

1. The CART approach can satisfactorily reproduce the bioassay-based, mainstem nutrient limitation patterns.

- It can provide complementary information on nutrient limitation since it can utilize the CBP tidal monitoring data, expanding the spatial & temporal extent of assessments to guide water-quality management.
- New bioassays are useful for validating and updating the CART models.

Key Messages

2. The mainstem showed modest changes in nutrient limitation, with less NoR and more N-limitation in 2007-2017 than 1992-2002.

- Long-term reductions in N load appear to have led to expanded areas with nutrient-limitation.
- Continued reductions are needed to achieve a less nutrient-saturated ecosystem.
- This study demonstrates the importance of the monitoring data from the CBP Partnership and the value of novel approaches for gaining insights from the available data sets.