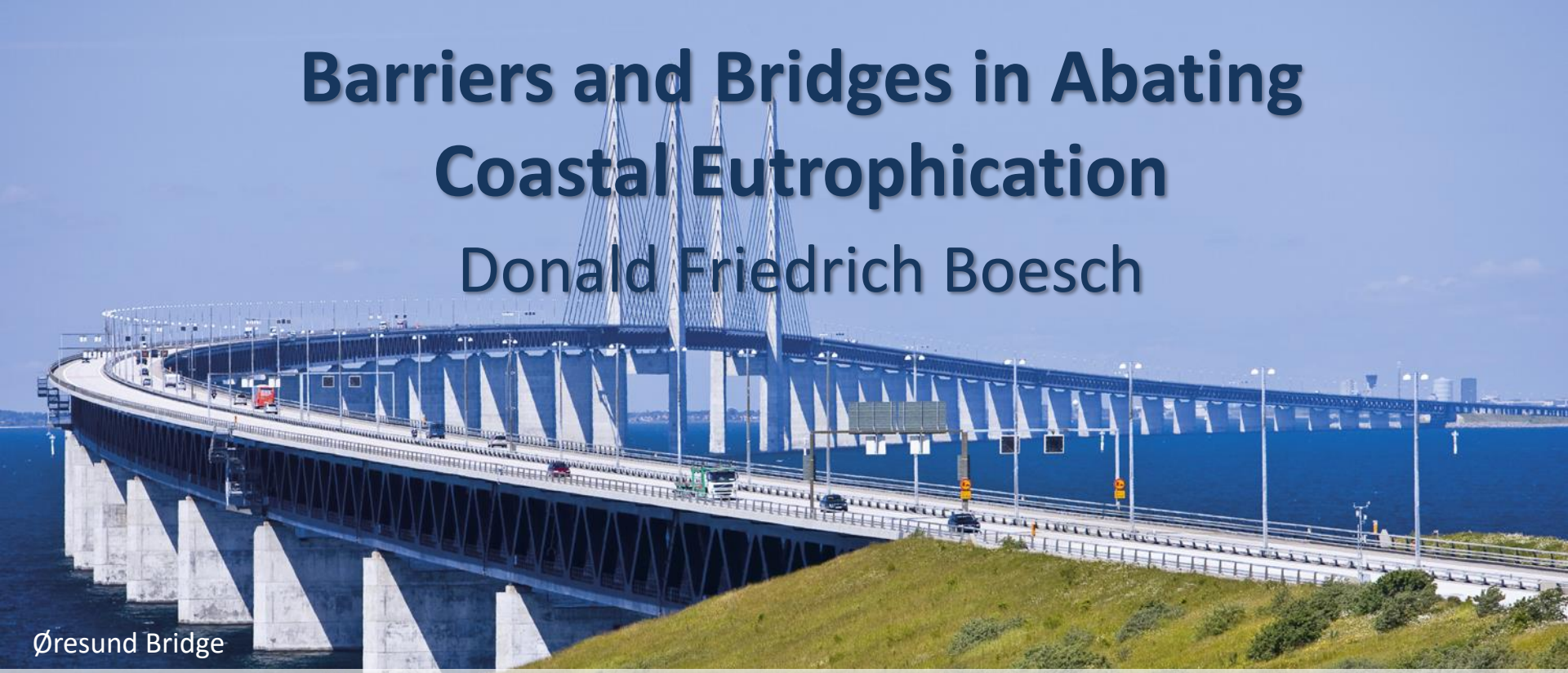
Barriers and Bridges in Abating Coastal Eutrophication

Donald Friedrich Boesch



Øresund Bridge

University of Maryland
Center for Environmental Science

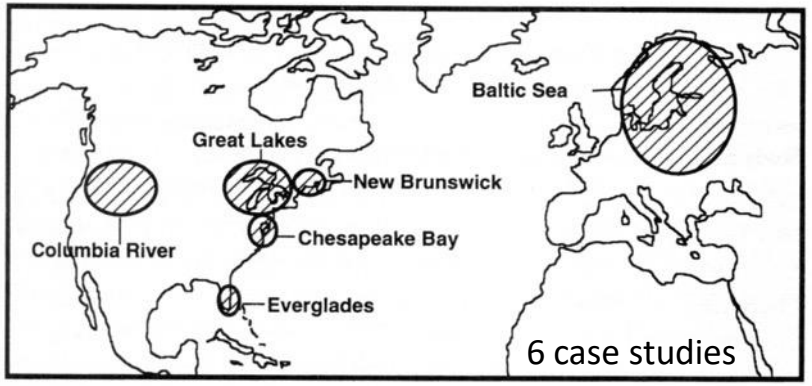
Scientific & Technical Advisory Committee
September 10, 2019

4th International Symposium on Research and Management of Eutrophication in Coastal Ecosystems (EUTRO 2018)

18-20 June 2018, Nyborg, Denmark

Boesch, D.F. 2019 Barriers and bridges in abating coastal eutrophication. *Frontiers in Marine Science*. Vol 6, Article 123

Barriers and Bridges



Bengt-Owe Jansson & Harold Velner:

- The Øresund bridge project . . . by some called a bridge, and by others a barrier
- Following the June 1994 decision to build the bridge, the Minister of Environment in Sweden and the Minister of Finance in Denmark resigned.

Eutrophication Abatement Campaigns

European Campaigns Considered

Greenland (U.S.)

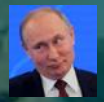
North Sea
OSPAR

Baltic Sea
HELCOM

EU Directives

- **Urban Waste Water Treatment**
- **Nitrates**
- **Water Framework**
- **Marine Strategy Framework**

North-East Atlantic
OSPAR

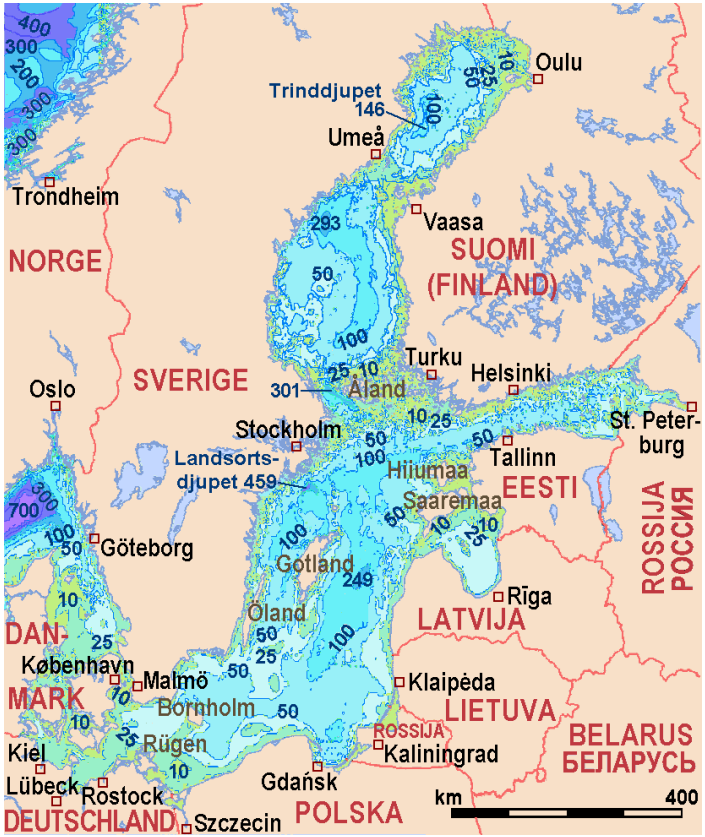


Black Sea
Budapest Commission

Adriatic Sea

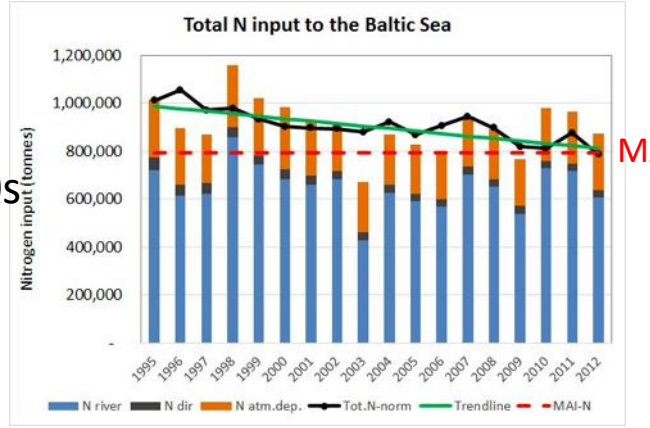
Mediterranean Sea
Barcelona Convention

Baltic Sea – the World Class Campaign

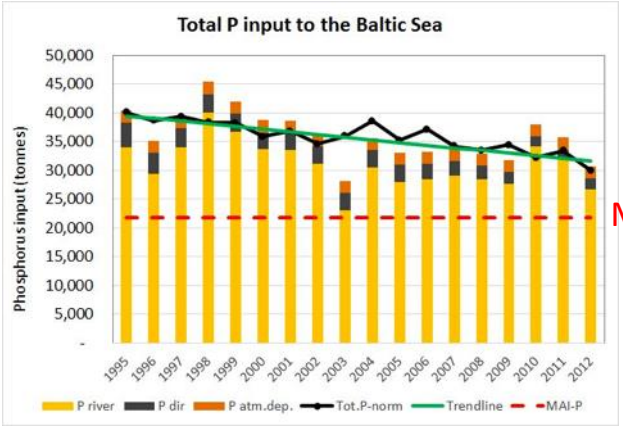


HELCOM 1988
-50% N&P by 1995
✓-24% N & -50% P >80s

Baltic Sea Action Plan 2013
Max. **A**llowable **I**nputs
-16% N & -70 % P by 2015 based on 1997-2003 loads



MAI

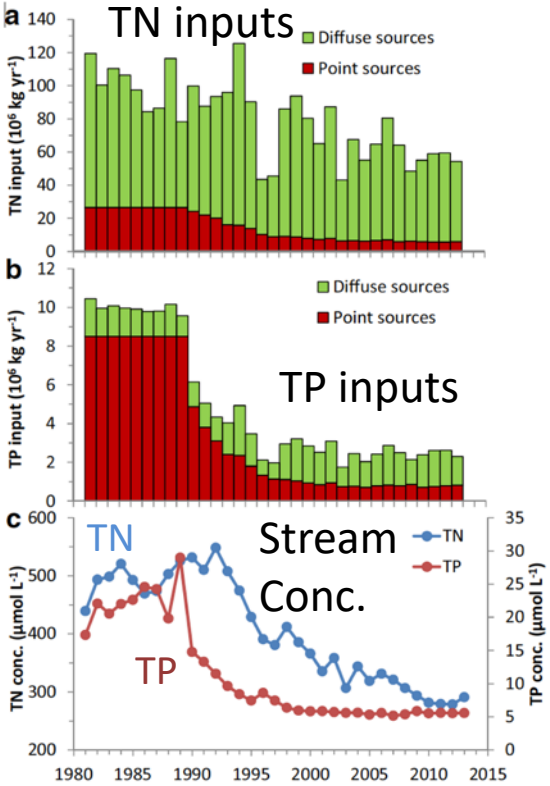


MAI

The Danish Experience

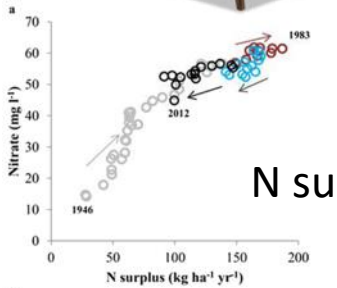
- 1987 National Action Plan on Aquatic Environment: -50% N & -80% P
- Additional agricultural measures, including N application 85-90% of economic optimum & mandatory cover crops
- >1988 sustained & coupled monitoring & assessment
- Inputs to coastal systems -50% N & -70% P

Riemann et al. 2016. *Estuaries & Coasts*

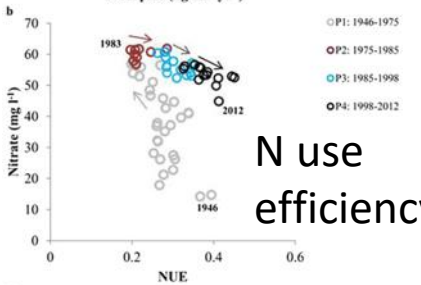


Hansen et al. 2017. *Scientific Reports*

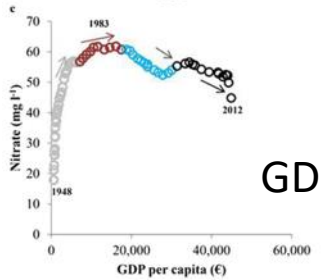
Average nitrate concentration in groundwater



N surplus



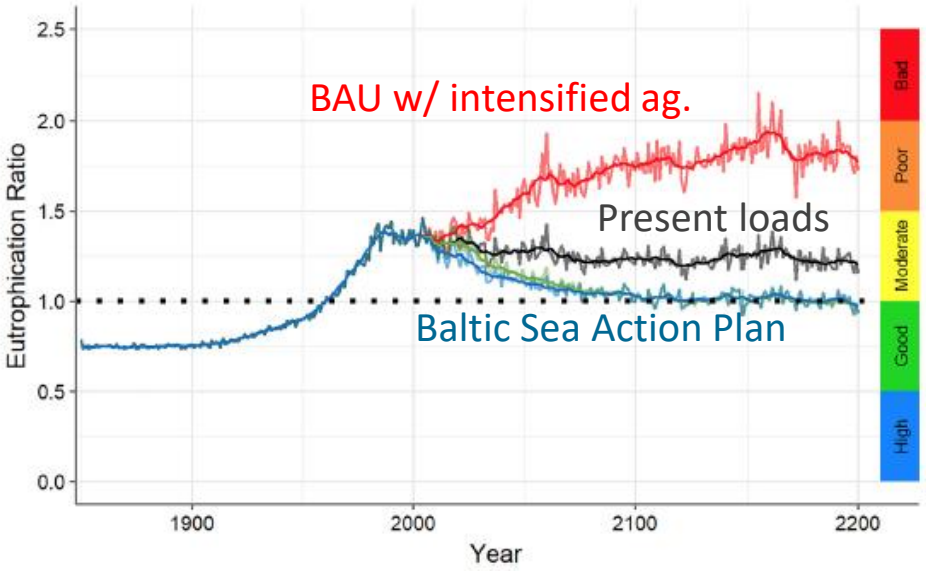
N use efficiency



GDP

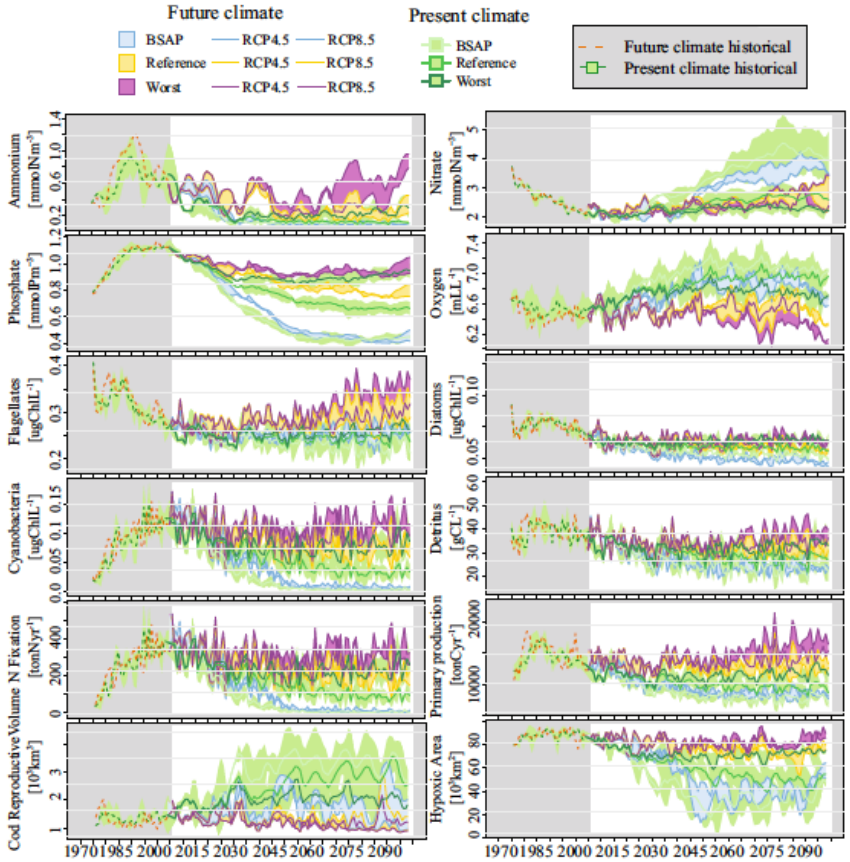
Modeling Future of Baltic

Recovery of eutrophication health index



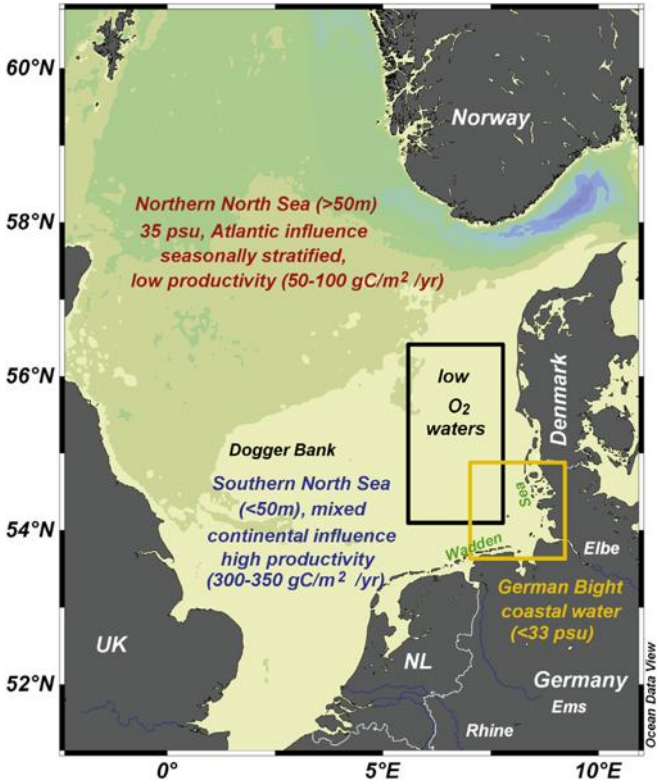
Murray et al. 2019. *Frontiers in Marine Science*

Compounding effects of climate change



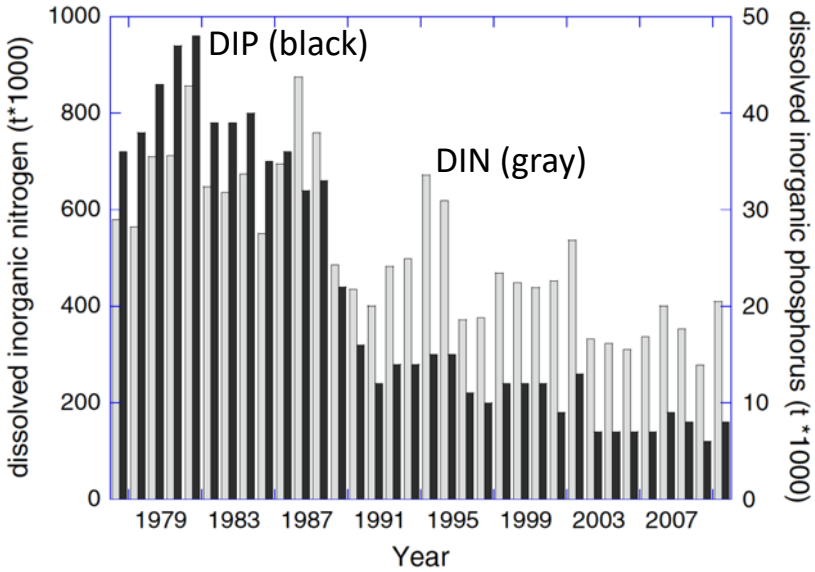
Saraiva et al. 2018. *Climate Dynamics*

Southern North Sea



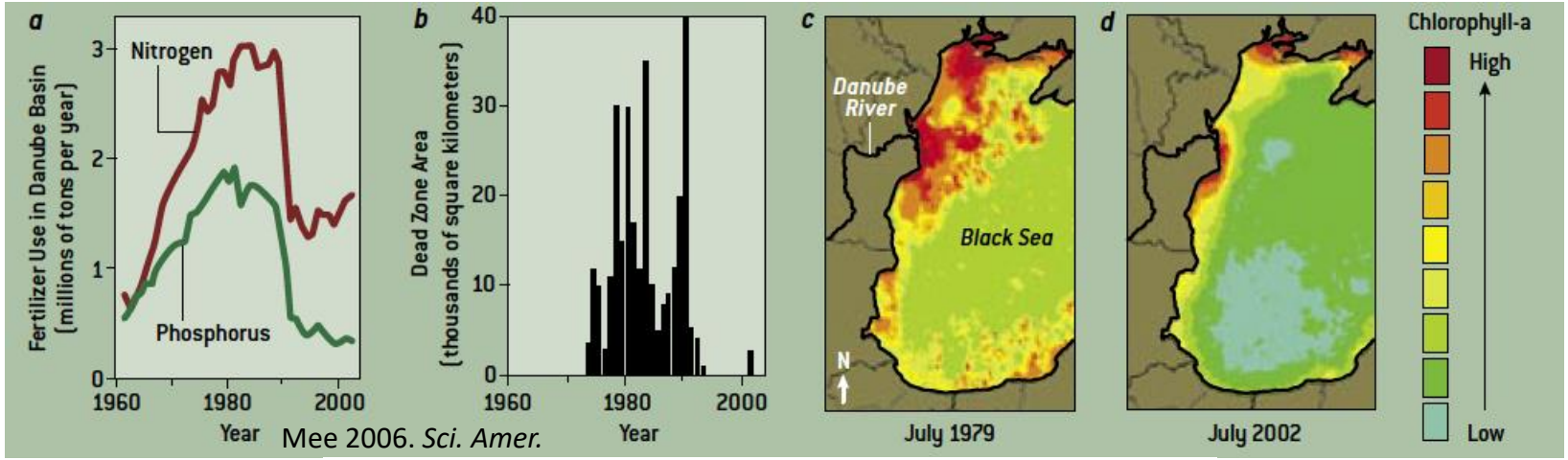
Emeis et al. 2015. *Journal of Marine Systems*

OSPAR 1987: reduce river loads of N and P by 50% between 1985 and 1995, P goal exceeded, N -~20%
By 2010 -81% P, -45% N

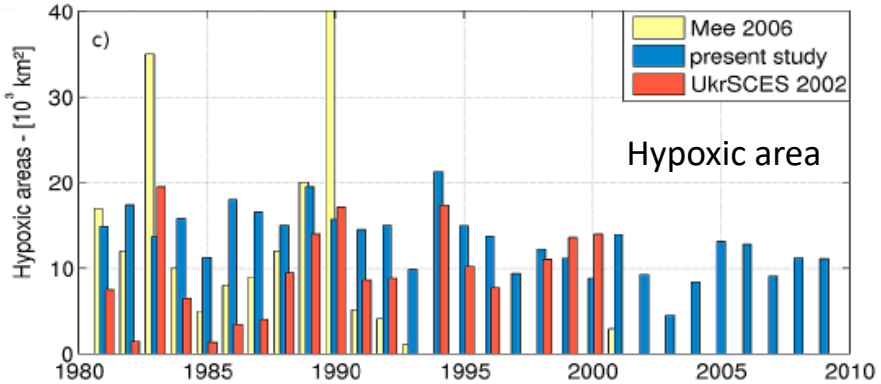


Annual loads from Elbe, Weser, Ems, Ijssel, Rhine, Scheldt & Meuse rivers

Black Sea: A Textbook Story Retold

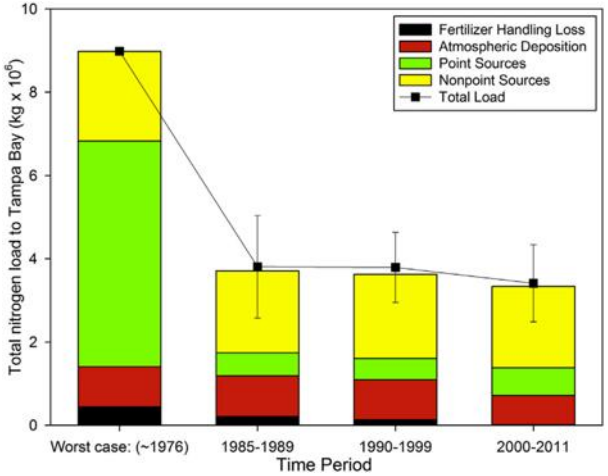


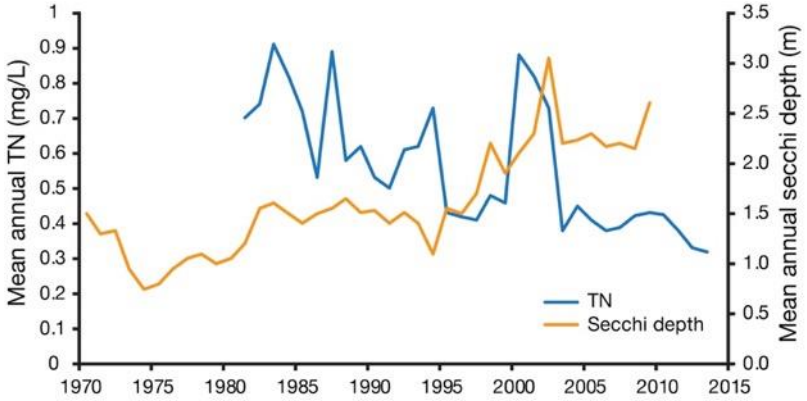
Mee 2006. *Sci. Amer.*

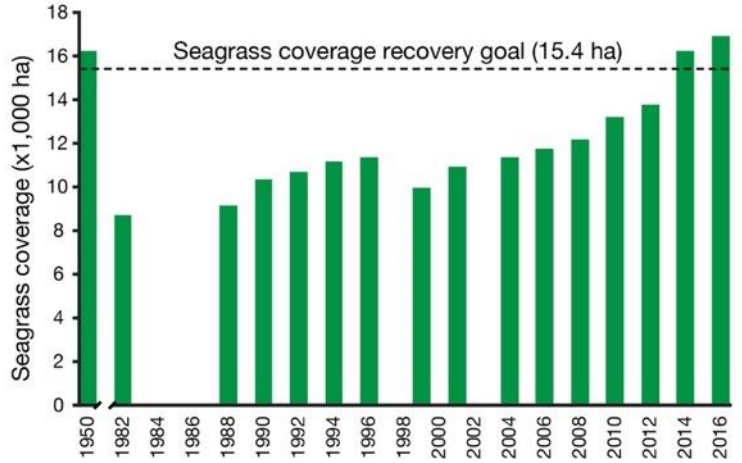


Capet et al. 2013. *Biogeosciences*

Tampa Bay: Impressive Reversal





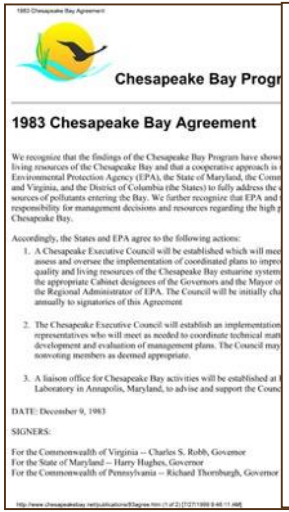


Greening et al. 2014. *Estuar. Coast. Shelf Sci.* 214:A1

Chesapeake Bay Agreements

Nutrient Source Reduction Goals

1983



Chesapeake Bay Progr

1983 Chesapeake Bay Agreement

We recognize that the findings of the Chesapeake Bay Program have shown living resources of the Chesapeake Bay and that a cooperative approach is Environmental Protection Agency (EPA), the State of Maryland, the Comm and Virginia, and the District of Columbia (the States) to fully address the sources of pollutants entering the Bay. We further recognize that EPA and responsibility for management decisions and resources regarding the high Chesapeake Bay.

Accordingly, the States and EPA agree to the following actions:

1. A Chesapeake Executive Council will be established which will mee assess and oversee the implementation of coordinated plans to impro quality and living resources of the Chesapeake Bay estuarine system the appropriate Cabinet designees of the Governors and the Mayor the Regional Administrator of EPA. The Council will be initially cha annually to signatories of this Agreement
2. The Chesapeake Executive Council will establish an implementation representatives who will meet as needed to coordinate technical matt development and evaluation of management plans. The Council may nonvoting members as deemed appropriate.
3. A liaison office for Chesapeake Bay activities will be established at Laboratory in Annapolis, Maryland, to advise and support the Counc

DATE: December 9, 1983

SIGNERS:

For the Commonwealth of Virginia -- Charles S. Robb, Governor
For the State of Maryland -- Harry Hughes, Governor
For the Commonwealth of Pennsylvania -- Richard Thornburgh, Governor

1987

1987 CHESAPEAKE BAY AGREEMENT

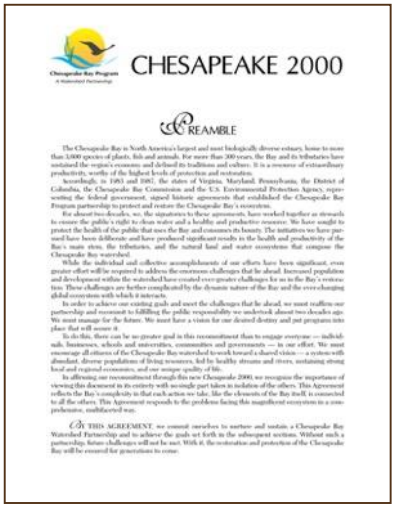
THE CHESAPEAKE BAY IS A NATIONAL TREASURE

and a resource of worldwide significance. Its ecological, economic, and cultural importance are felt far beyond its waters and the communities that line its shores. Man's use and abuse of its bounty, however, together with the continued growth and development of population in its watershed, have taken a toll on the Bay system. In recent decades, the Bay has suffered serious declines in quality and productivity. ✧ REPRESENTING the Federal government and the States which surround the Chesapeake Bay, we acknowledge our stake in the resources of the Bay and accept our share of responsibility for its current condition. We are determined that this decline will be reversed. In response, all of our jurisdictions have embarked on ambitious programs to protect our shared resource and restore it to a more productive state. ✧ IN 1980, the legislatures of Virginia and Maryland established the Chesapeake Bay Commission to coordinate interstate planning and programs from a legislative perspective. In 1985, Pennsylvania joined the Commission. And, in 1983, Virginia, Maryland, Pennsylvania, the District of Columbia, the U.S. Environmental Protection Agency and the Chesapeake Bay Commission formally agreed to a cooperative approach to this undertaking and established specific mechanisms for its coordination. Since 1983, our joint commitment has carried us to new levels of governmental cooperation and scientific understanding. It has formed a firm base for the future success of this long-term program. The extent and complexity of our task now call for an expanded and refined agreement to guide our efforts toward the twenty-first century. ✧ RECOGNIZING that the Chesapeake Bay's importance transcends regional boundaries, we commit to managing the Chesapeake Bay as an integrated ecosystem and pledge our best efforts to achieve the goals in this Agreement. We propose a series of objectives that will establish a policy and institutional framework for continued cooperative efforts to restore and protect Chesapeake Bay. We further commit to specific actions to achieve those objectives. The implementation of these commitments will be reviewed annually and additional commitments developed as needed.

GOALS AND PRIORITY COMMITMENTS

THIS NEW AGREEMENT CONTAINS Goals and Priority Commitments for Living Resources, Water Quality, Population Growth and Development, Public Information, Education and Participation, Public Access, and Governance. ✧ The parties to the 1987 Agreement are the U.S. Environmental Protection Agency representing the Federal government, the District of Columbia, the State of Maryland, and the Commonwealths of Pennsylvania and Virginia. (hereinafter the "States") and the Chesapeake Bay Commission. This Agreement may be amended and simultaneous added to the future by unanimous action of the Chesapeake Executive Council.

2000



CHESAPEAKE 2000

PREAMBLE

The Chesapeake Bay is North America's largest and most biologically diverse estuary, home to more than 3,000 species of plants, fish and animals. For more than 300 years, the Bay and its tributaries have sustained the region's economy and defined its traditions and culture. It is a resource of extraordinary productivity, worthy of the highest levels of protection and restoration.

Accordingly, in 1983 and 1987, the states of Virginia, Maryland, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission and the U.S. Environmental Protection Agency, representing the federal government, signed historic agreements that established the Chesapeake Bay Program partnership to protect and restore the Chesapeake Bay's ecosystem.

For almost two decades, we, the signatories to these agreements, have worked together as stewards to ensure the public's right to clean water and a healthy and productive resource. We have sought to protect the health of the public that uses the Bay and consumes its bounty. The initiatives we have pursued have been deliberate and have produced significant results in the health and productivity of the Bay's main river, the tributaries, and the natural land and water ecosystems that compose the Chesapeake Bay watershed.

While the individual and collective accomplishments of our efforts have been significant, even greater effort will be required to address the enormous challenges that lie ahead. Increased population and development within the watershed have created ever-greater challenges for us in the Bay's restoration. These challenges are further complicated by the dynamic nature of the Bay and the ever-changing global ecosystem with which it interacts.

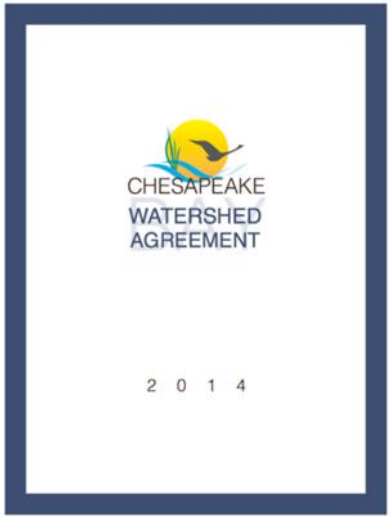
In order to achieve our existing goals and meet the challenges that lie ahead, we must reaffirm our partnership and recommit to fulfilling the public responsibility we undertook almost two decades ago. We must manage for the future. We must have a vision for our desired destiny and put programs into place that will secure it.

To do this, there can be no greater goal in this recommitment than to engage everyone — individuals, businesses, schools and universities, communities and governments — in our effort. We must encourage all citizens of the Chesapeake Bay watershed to work toward a shared vision — a system with abundant, diverse populations of living resources, fed by healthy streams and rivers, sustaining strong local and regional economies, and our unique quality of life.

In affirming our recommitment through this new Chesapeake 2000, we recognize the importance of viewing this document in its entirety with no single part taken in isolation of the others. This Agreement reflects the Bay's complexity in that each action we take, like the elements of the Bay itself, is connected to all the others. This Agreement responds to the problems facing this magnificent ecosystem in a comprehensive, multifaceted way.

BY THIS AGREEMENT, we commit ourselves to nurture and sustain a Chesapeake Bay Watershed Partnership and to achieve the goals set forth in the subsequent sections. Without such a partnership, future challenges will not be met. With it, the restoration and protection of the Chesapeake Bay will be ensured for generations to come.

2014



CHESAPEAKE WATERSHED AGREEMENT

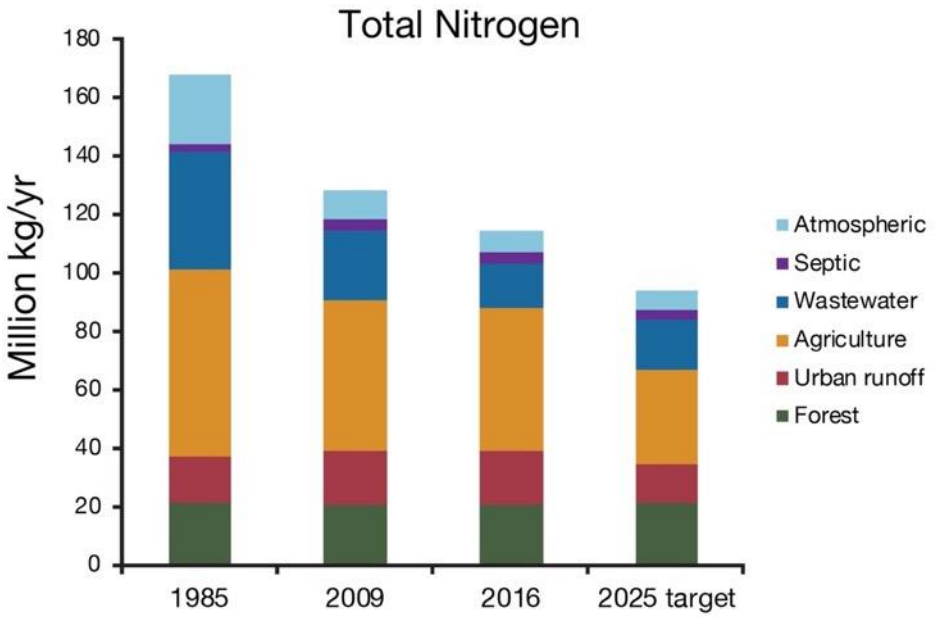
2 0 1 4

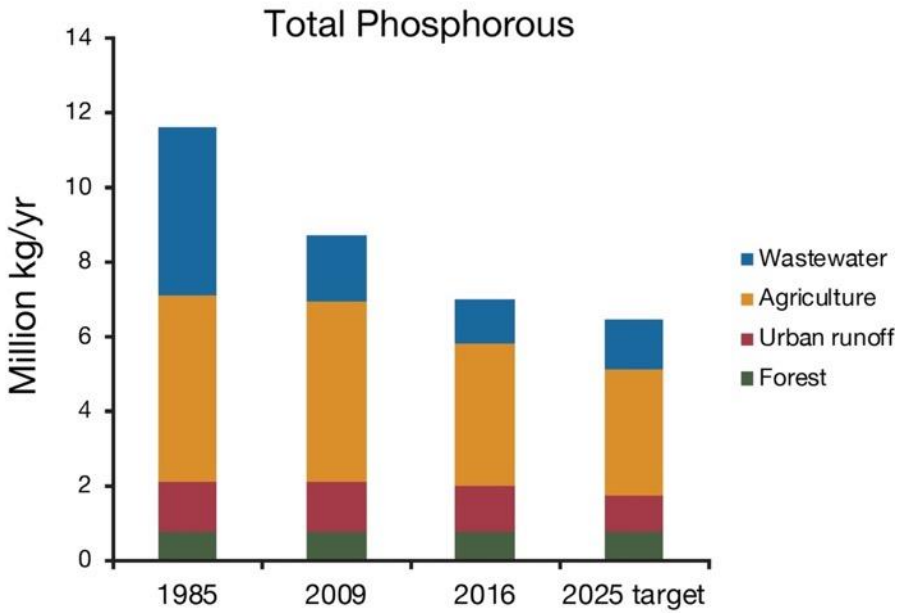
2025?

1987 — 40% reduction in N & P loads → 2000 — Voluntary reductions determined by science → 2010 — Mandatory Total Maximum Daily Load → 2025

Estimated Nutrient Load Reductions Achieved

Except for Direct Wastewater Discharges, Estimated by Models



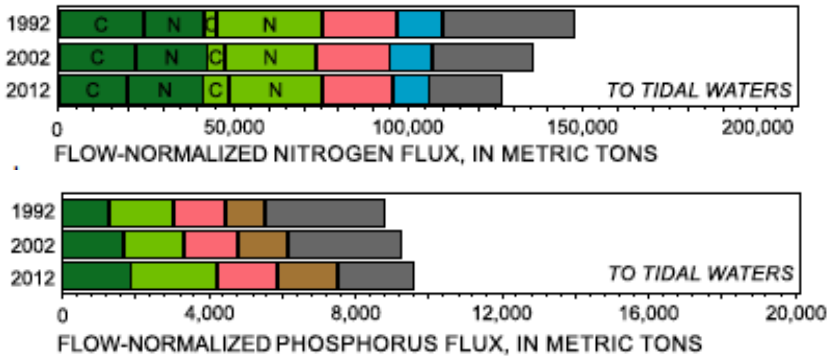


Boesch 2019. *Frontiers in Marine Science*

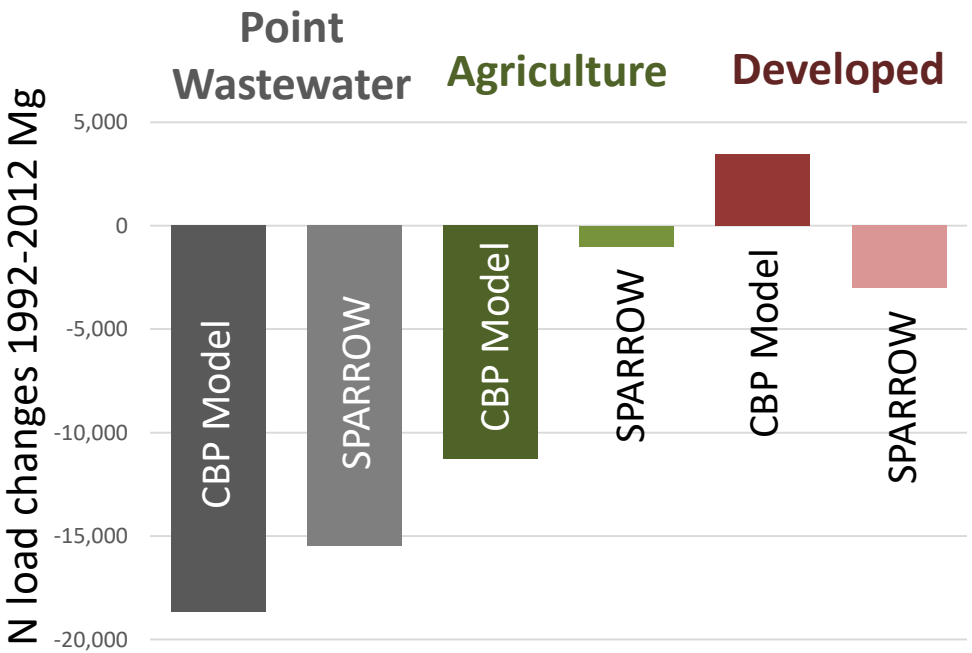
Based on www.chesapeakeprogress.com; more recent model estimates differ in categories and amounts

A Tale of Two Models

CBP Watershed & SPARROW



N flux declined 14%
>80% due to point sources
13% atmospheric deposition
agricult. inputs changed little

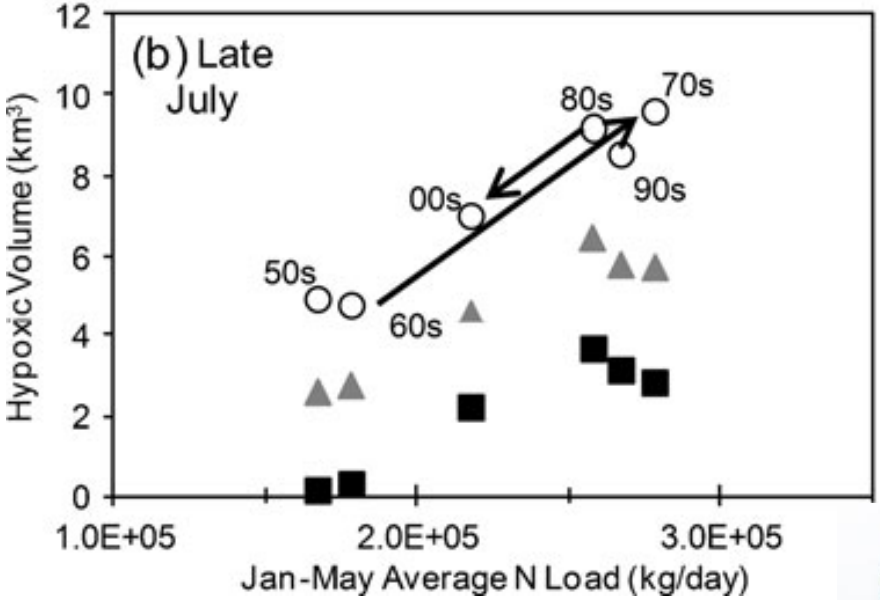


Ator, et al. 2019. Toward explaining nitrogen and phosphorus trends in Chesapeake Bay tributaries, 1992-2012. *JAWRA*

Chesapeake Bay Indicators of Recovery

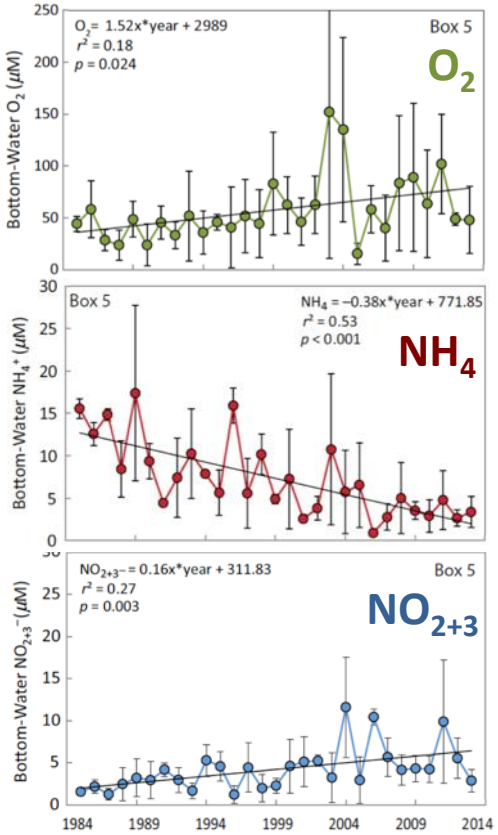
Hypoxia

○ <2 mg/L ▲ <1 mg/L ■ <0.2 mg/L



Murphy et al. 2011 *Estuaries & Coasts* 34:1293

Nutrient cycling



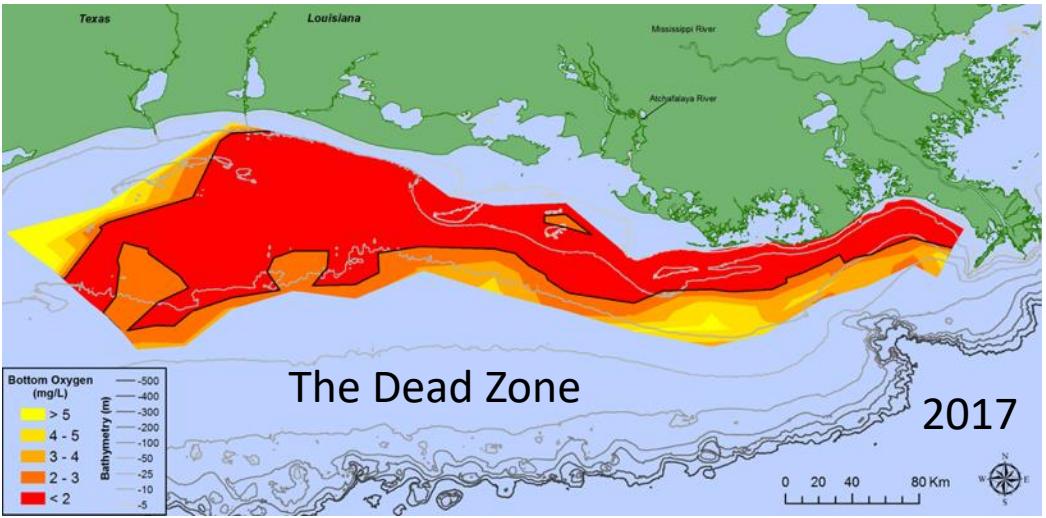
Testa et al. 2018 *L&O*

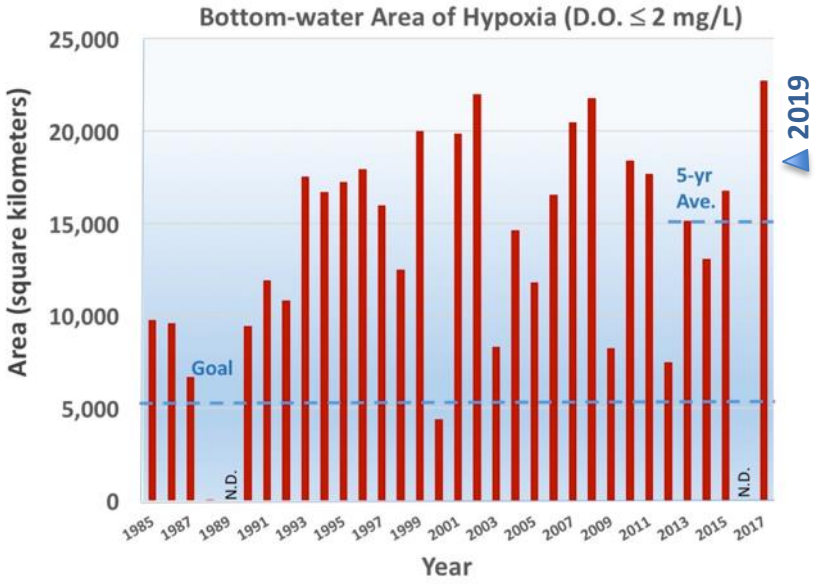
Northern Gulf of Mexico Hypoxia

Mississippi River Gulf of Mexico Watershed Nutrient Task Force

2000 Integrated Assessment
2001 Action Plan
2007 EPA SAB Report
2008 Action Plan

<5,000 km^2 by 2015 ➔ 2035
~-45% N & P, interim goal -20% by 2025
Voluntary Action (no TMDL)
Task Force – 12 states & Federal agencies

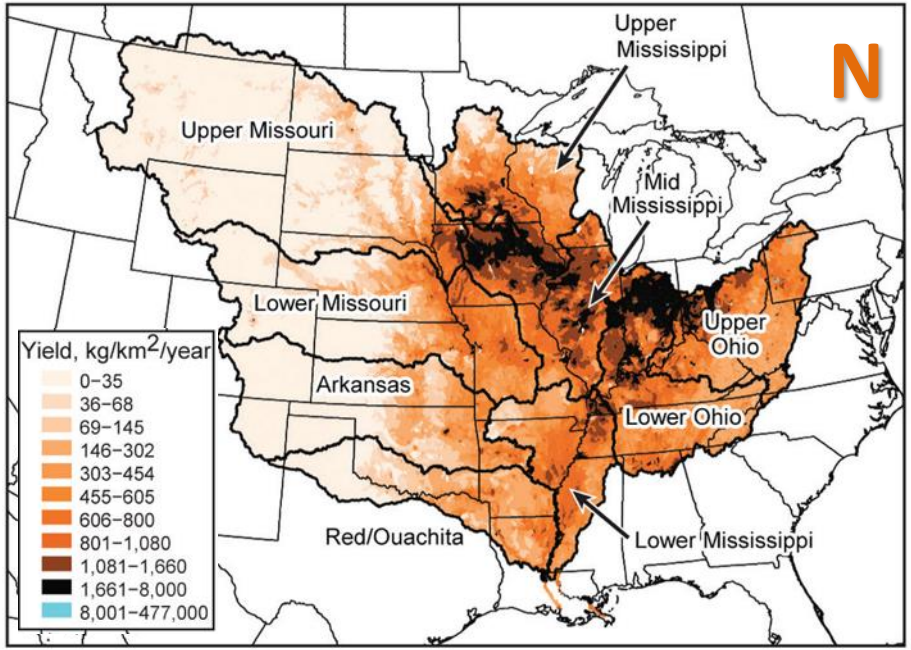




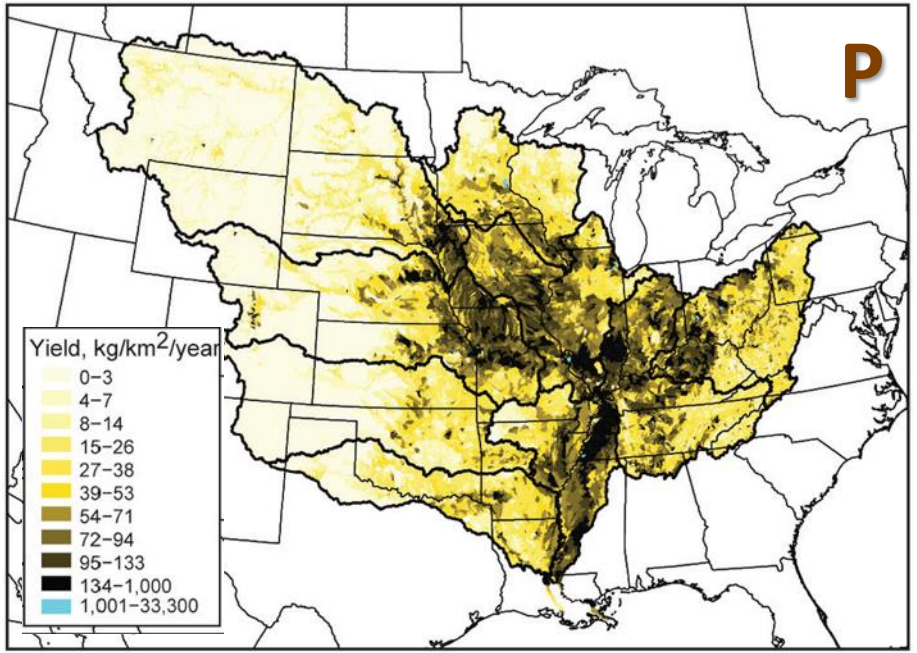
gulfhypoxia.net/research/shelfwide-cruises/

Mississippi River Basin Delivered Yields

Delivered Incremental N Yield



Delivered Incremental P Yield

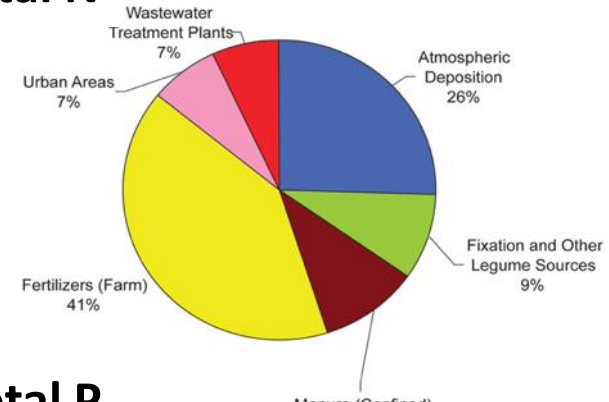


Spatially Referenced Regression on Watershed Attributes (SPARROW) Model

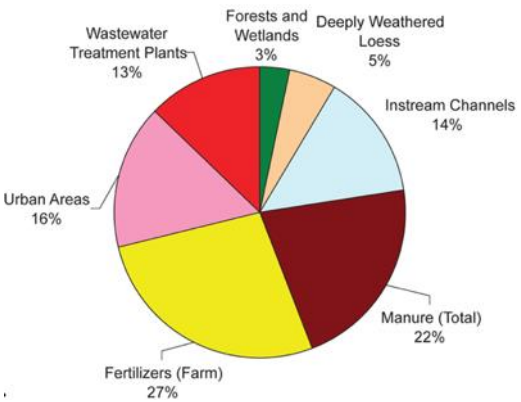
Robertson & Saad 2014 *Journal of Environmental Quality* 42:1422

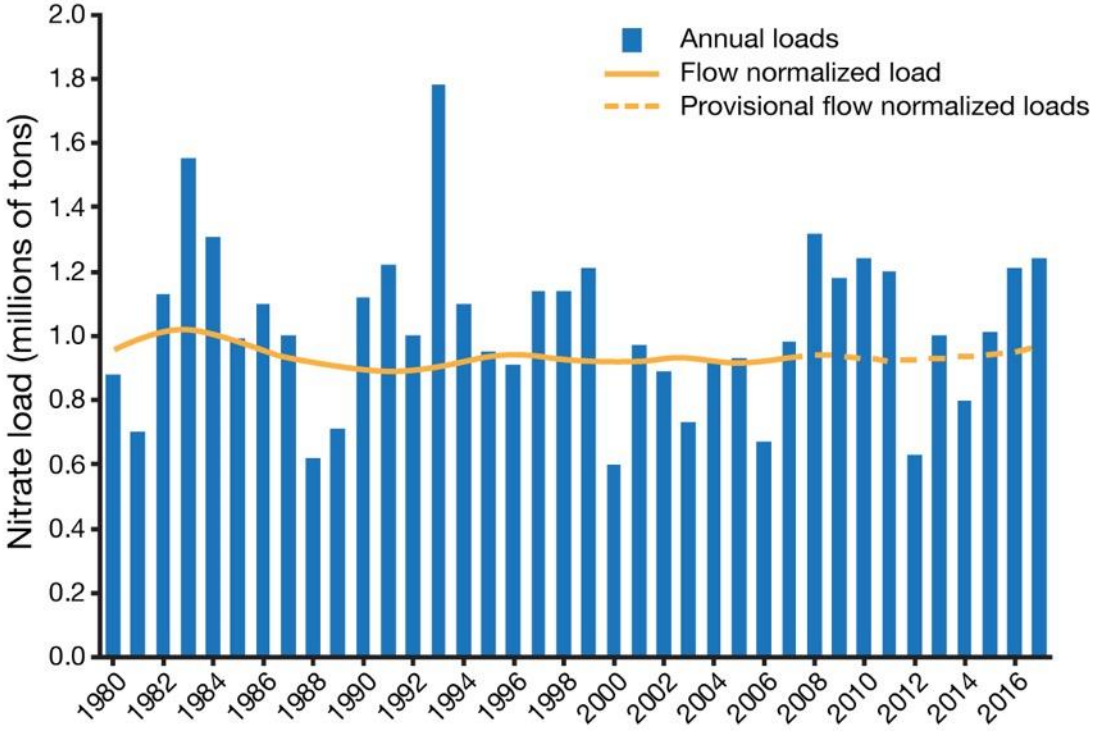
Mississippi River Basin Sources & Trends

Total N



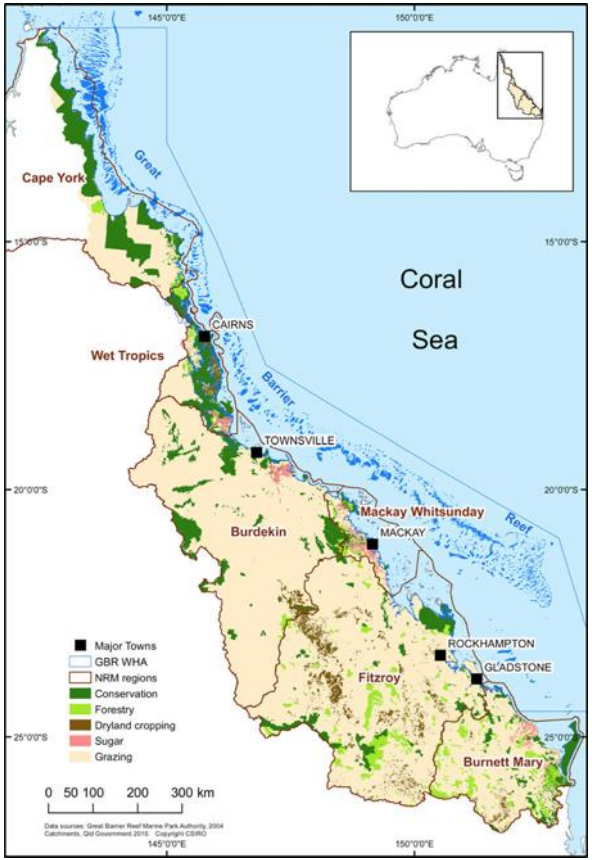
Total P

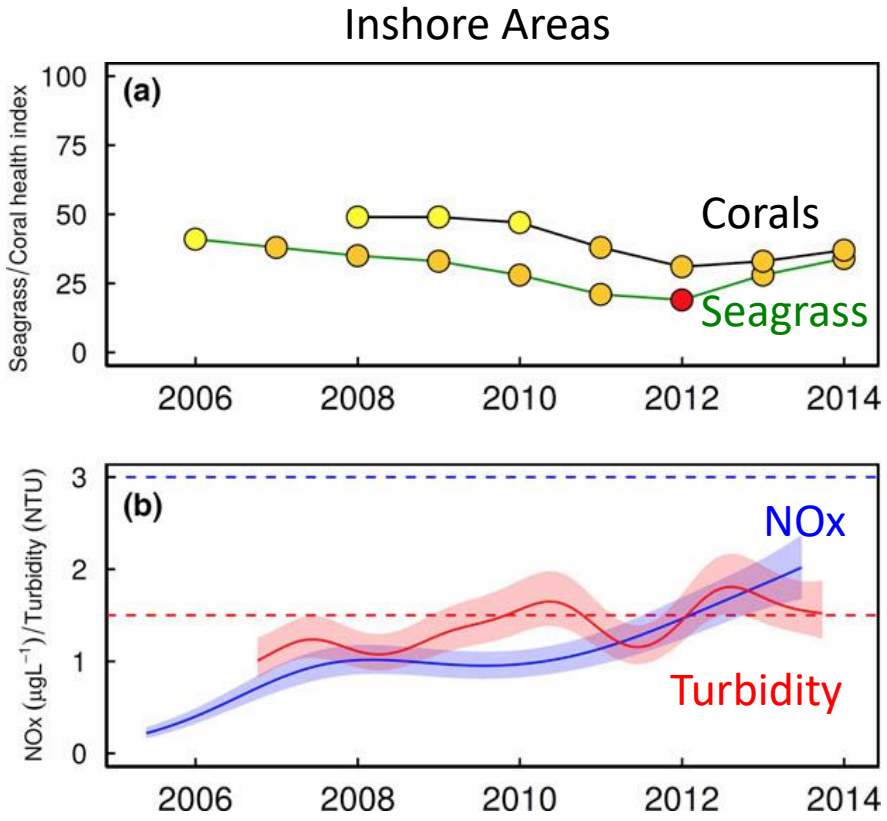




Boesch. 2019. *Frontiers in Marine Science*

Great Barrier Reef: No Sanctuary





Kroon et al. 2016 *Global Change Biology* 22: 1985

- Agriculture
- Reef Plans 2013 & 2050
- Efforts insufficient
- Hydrological restoration
- Changes in production

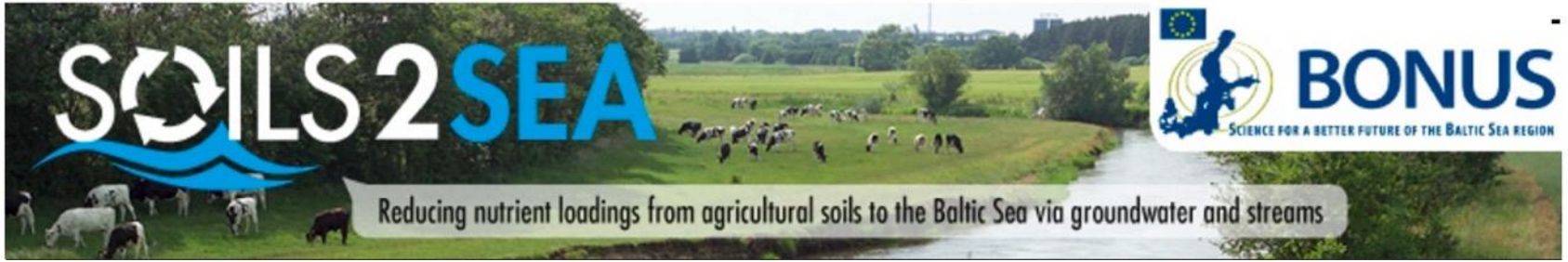
Barriers and Bridges 1

Themes	Barriers	Bridges
Advancing actionable science	Limited knowledge of causes	Apply knowledge/approaches
	Fragmentary understanding	Client-responsive strategic research
	Paralyzing controversies	Responsive, conclusive adjudication
Providing accountable governance	Managers lack authority & responsibility	Enduring engagement of high-level parties
	Limited stakeholder engagement	Effective communication
	Overgeneralized commitments	Allocation & accountability
	Non-binding commitments	Statutory requirements

BONUS

SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

Client-Responsive Strategic Research



Barriers and Bridges 1

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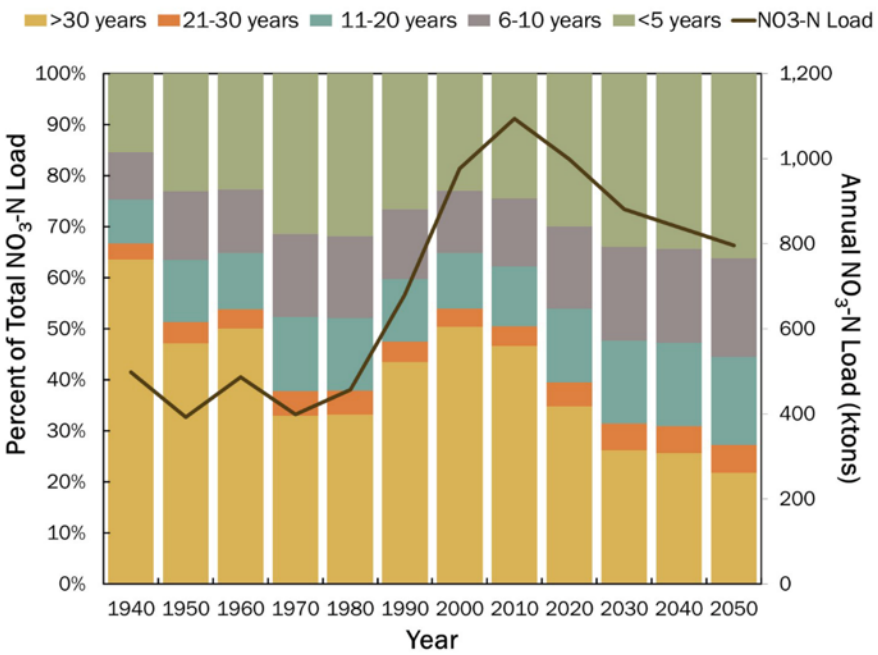
	Non-binding commitments	Statutory requirements

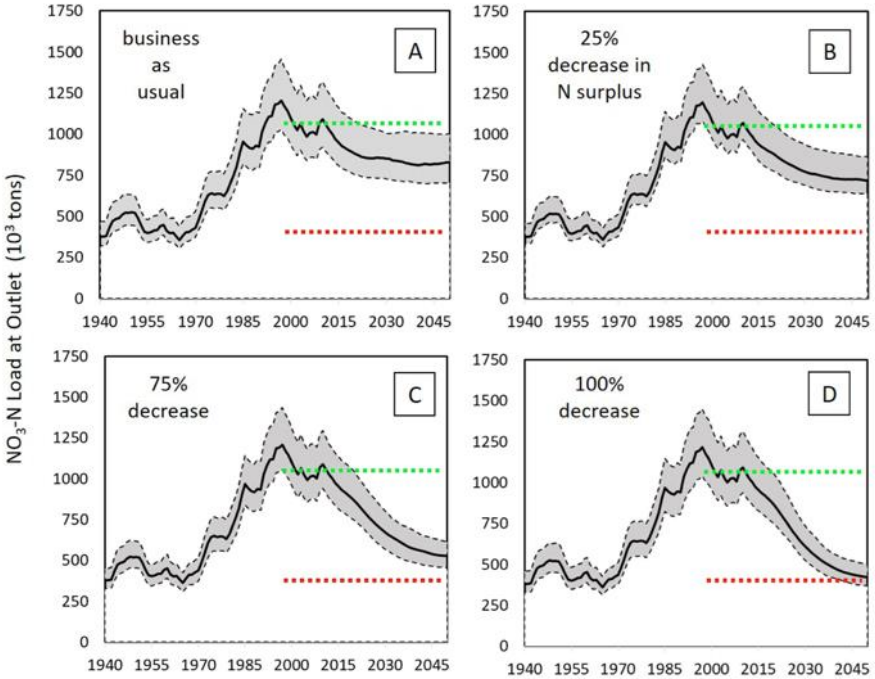
Barriers & Bridges 2

Theme	Barriers	Bridges
Reducing nutrient loads	Debates over limiting nutrients	Holistic N & P strategies
	Atmospheric sources out of control of water mgrs.	Air quality regulations reduce N loads
	Voluntary implementation	Performance compliance
	Expansion of biofuels	Transition to cellulosic biofuels
	Legacies and lags	Focus on sources with more immediate pathways

Legacies in Mississippi River Basin

Van Meter et al. 2018 *Science* eaar4462





But see comment by Ballard et al. and response by Van Meter et al. in *Science*!

Barriers and Bridges 3

Theme	Barriers	Bridges
Assessing outcomes & adapting strategies	Inadequate/underused monitoring	Sustained monitoring of key indicators, processes
	Inadequate/over-prescribed modeling	Multiple models guide management
	Models not reconciled	Truly adaptive management
	Rehabilitation recalcitrant	Intervention in coastal ecosystem
Addressing climate change	Goals practically unachievable	Reassess to inform climate-smart strategies
	Decoupled water-quality & climate strategies	Alternatives that address climate change & loads

Break barriers, build bridges.

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Chesapeake Bay Bridge
Photo: Ben Schumin