Can Oysters Really Provide Nutrient Reductions in Chesapeake Bay?

If so, can they help us meet our water quality improvement goals?

Mark Luckenbach
Virginia Institute of Marine Science
College of William and Mary

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NCBO – Sponsored Workshop
Jan. 10 – 11, 2013
Wachapreague, VA

Purpose: To gather experts to determine: (1) the best available values for nitrogen removal by oysters; (2) the uncertainty associated with these estimates; and, (3) the data gaps necessary to reduce the uncertainty

Moderated by Kevin Sellner (CRC)

Participants –

Lisa Kellogg (VIMS)
Mark Luckenbach (VIMS)
Jeff Cornwell (UMCES)
Mike Owens (UMCES)
Line zu Ermgassen (Cambridge)
Peter Bergstrom (NCBO)
Howard Townsend (NCBO)
Susan Connor (ACOE)
Doug Lipton (MD Sea Grant)
Troy Hartley (VA Sea Grant)
Steve Brown (TNC)

Mike Piehler (UNC)
Ruth Carmichael (USAB)
Bonnie Brown (VCU)
Wally Fulweiller (U. Mass)
Ken Paynter (UMD)
Stephanie Westby (NCBO)
Steve Allen (ORP)
Eric Weissberger (MD DNR)
Fredrika Moser (MD Sea Grant)
Boze Hancock (TNC)

Mark Brush (VIMS)
Iris Anderson (VIMS)
B.K. Song (VIMS)
Suzy Avvasian (EPA)
Annie Murphy (VIMS)
Bruce Vogt (NCBO)
Angie Sowers (ACOE)
Jim Wesson (VMRC)

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The Bay Program Management Board requested that STAC review the use of shellfish as a method of nutrient reduction and advise on how this can be incorporated into nutrient reduction practices.

STAC Panel Members

Mark Luckenbach – Virginia Institute of Marine Science
Donna Bilkovic - Virginia Institute of Marine Science
Gene Yagow – Virginia Tech
Randy Chambers – College of William & Mary, Biology
Michael Ford – National Oceanic & Atmospheric Administration
Jack Meisinger – National Marine Fisheries Service
Charles Bott – Hampton Roads Sanitation District

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A brief review…

www.dnr.sc.gov

Oysters are filter-feeders. They filter *stuff* out of the water.

The *stuff* that most TMDLs seek to reduce is nitrogen (N).

Oysters don't filter N, they filter phytoplankton that contain N.

So, what happens to the N when they filter phytoplankton?

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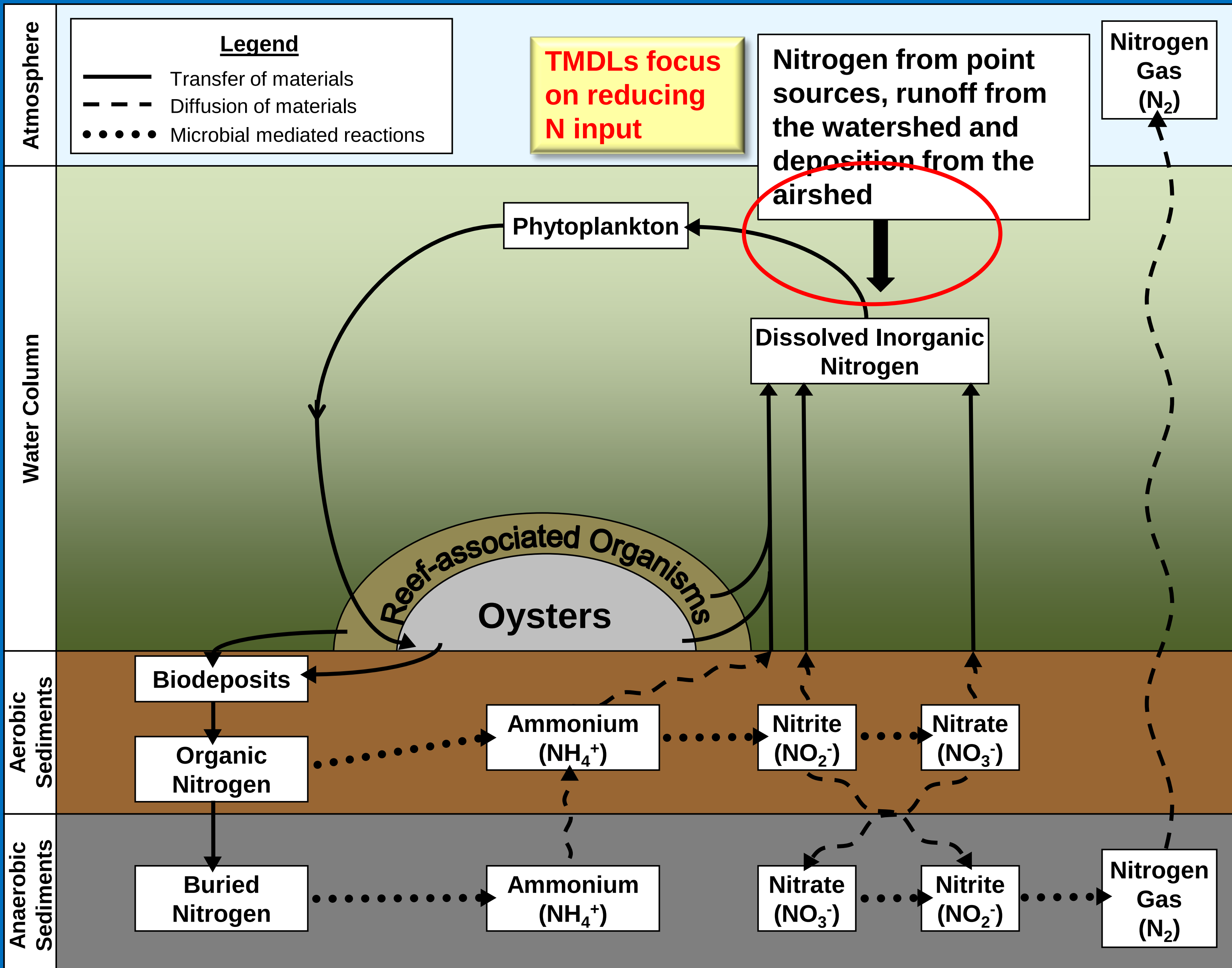
Nitrogen Cycling on Oyster Reefs



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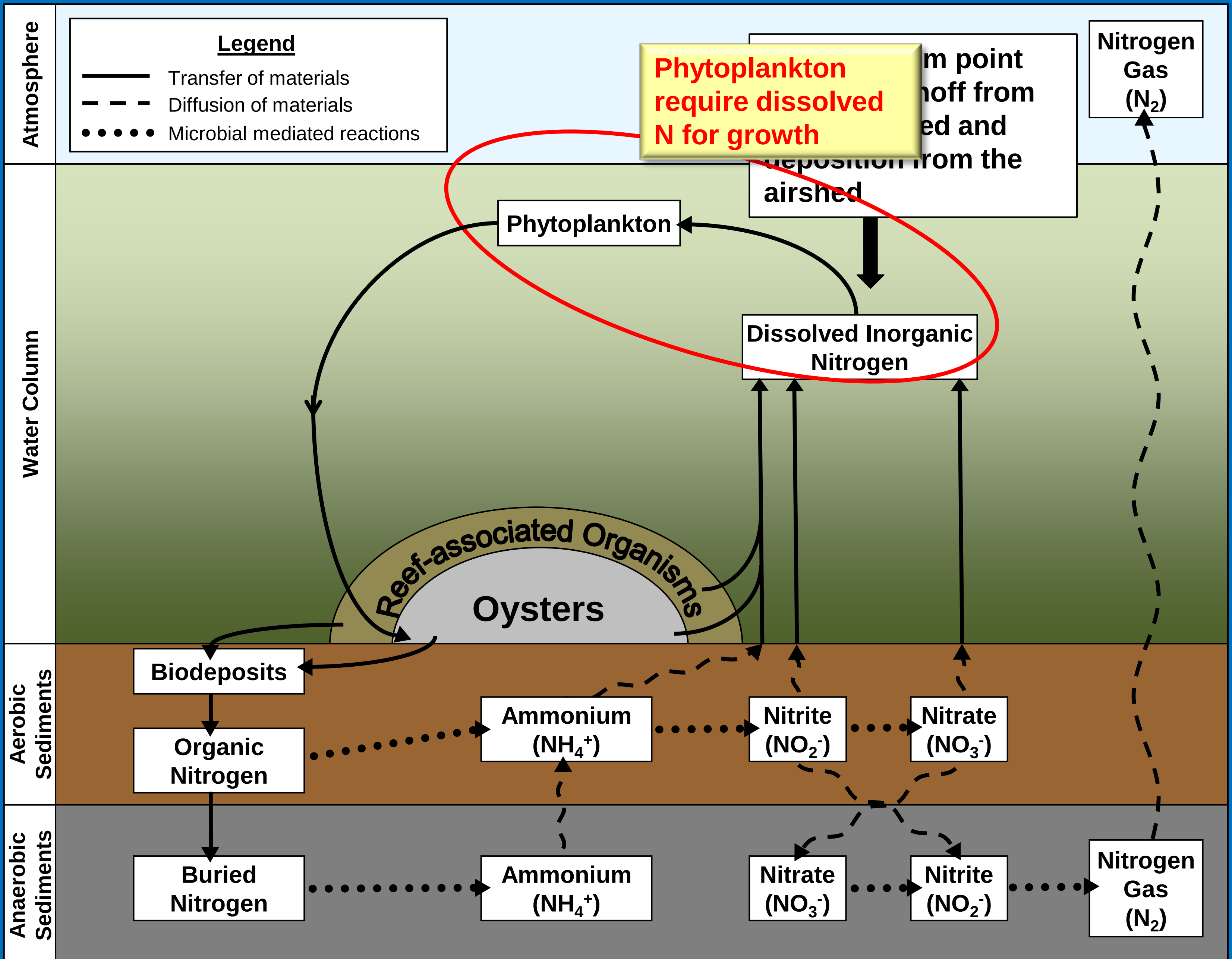

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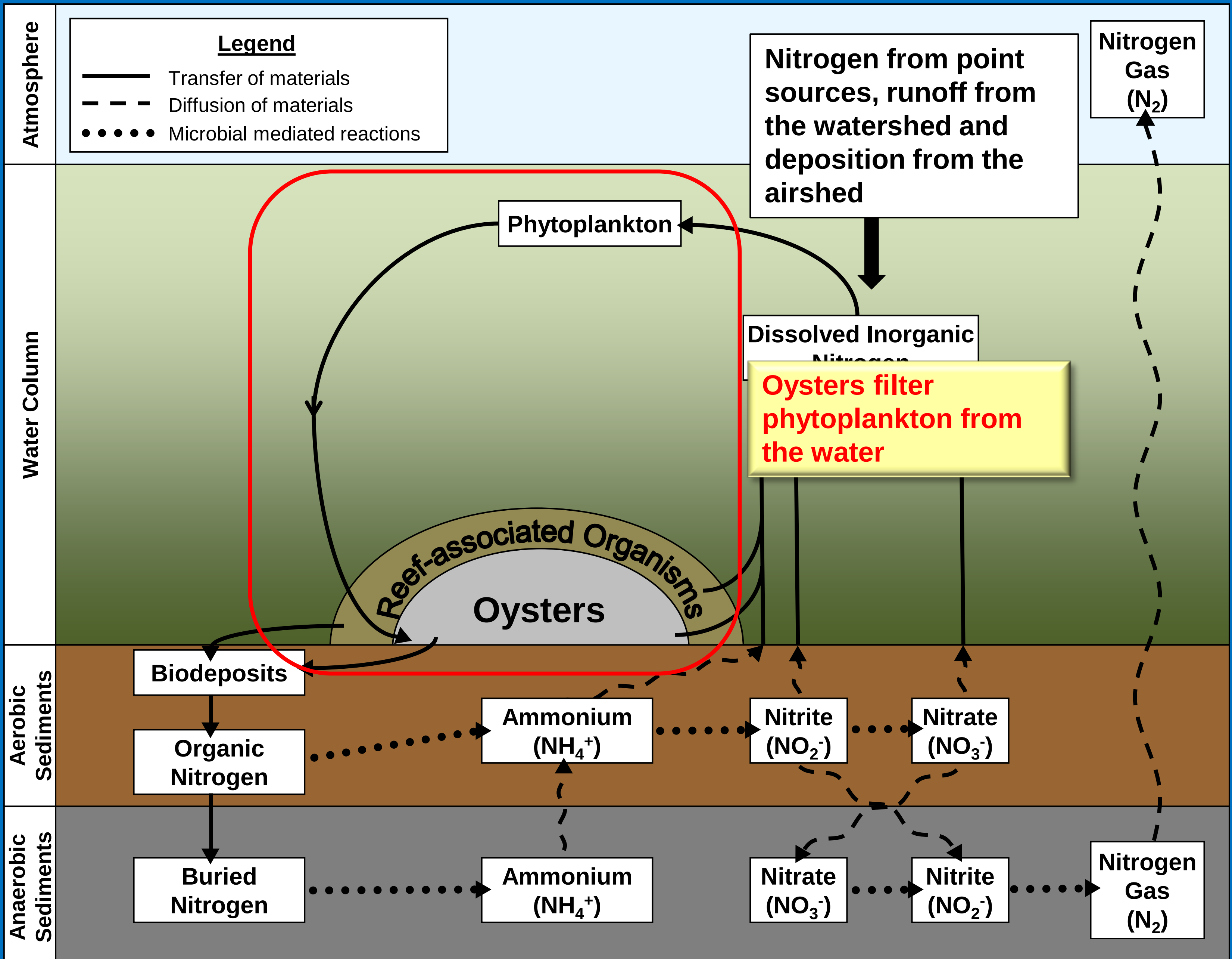

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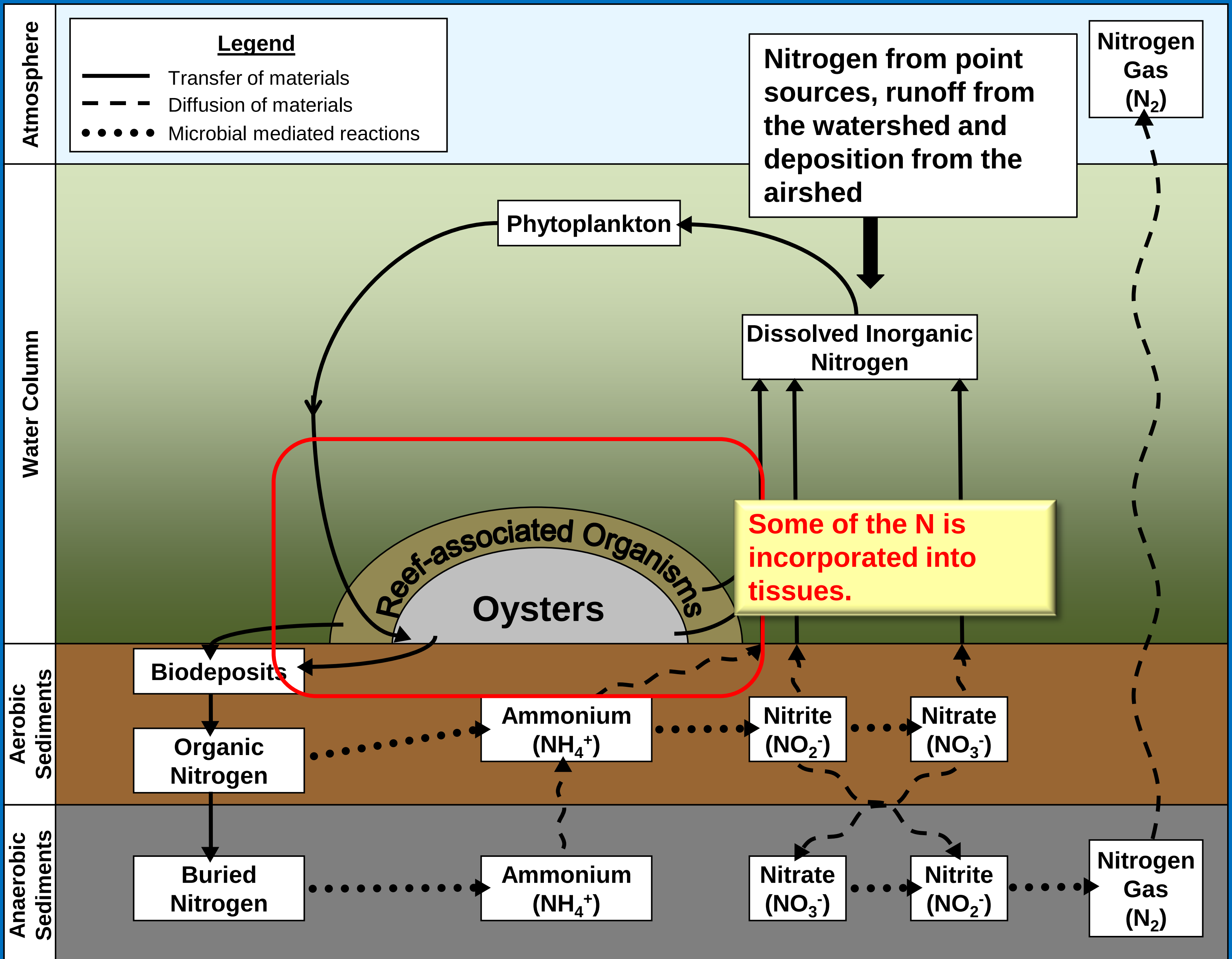

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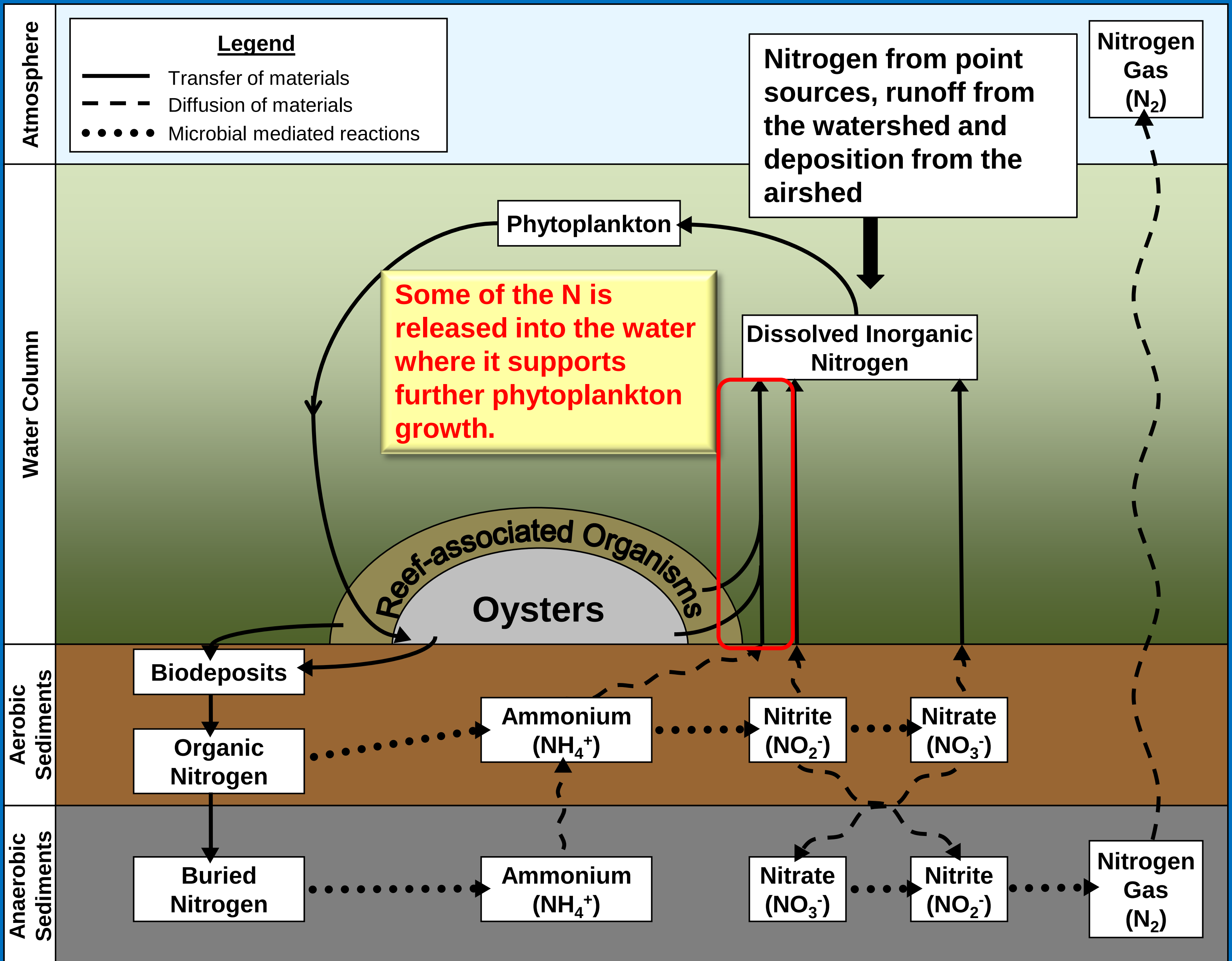

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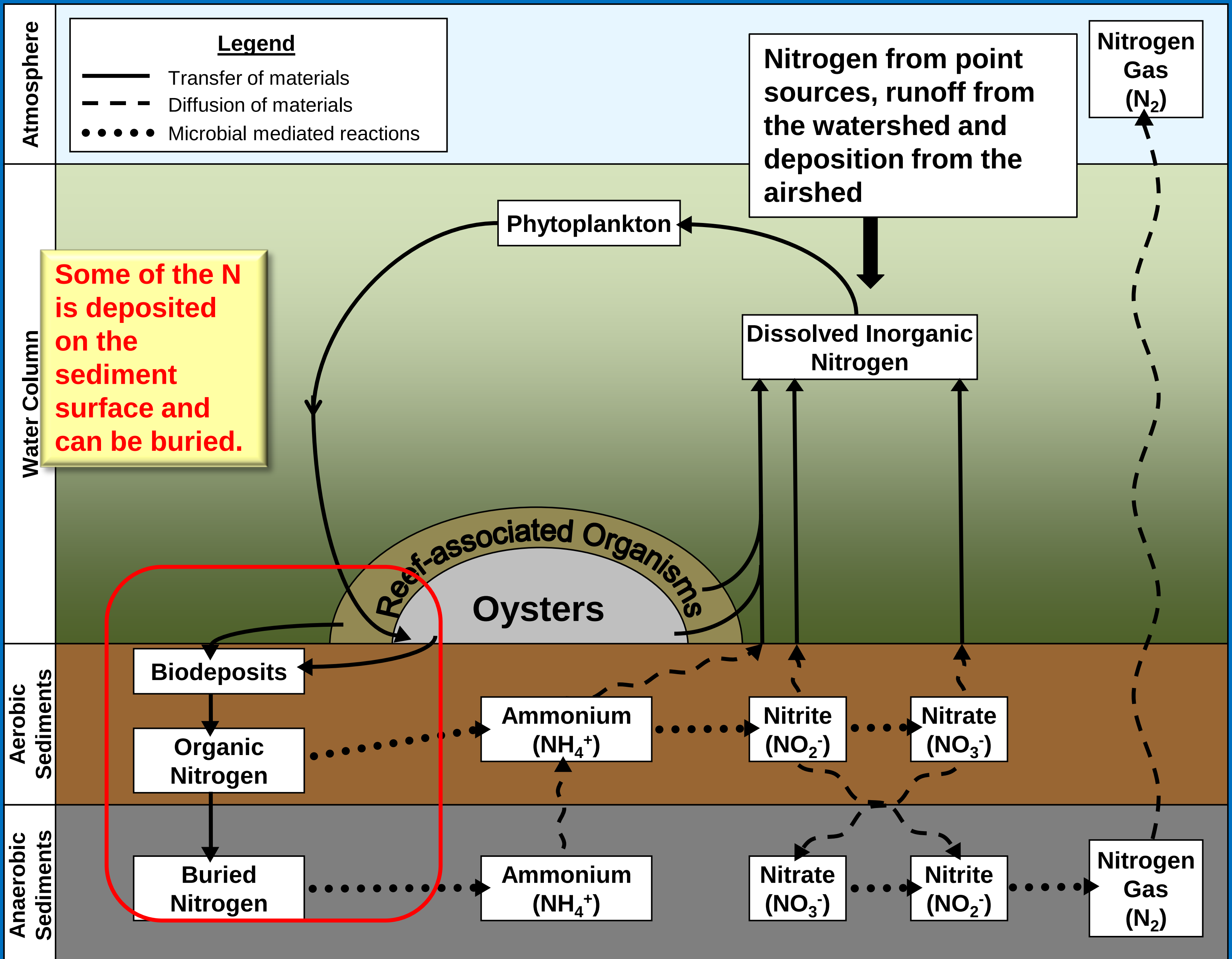

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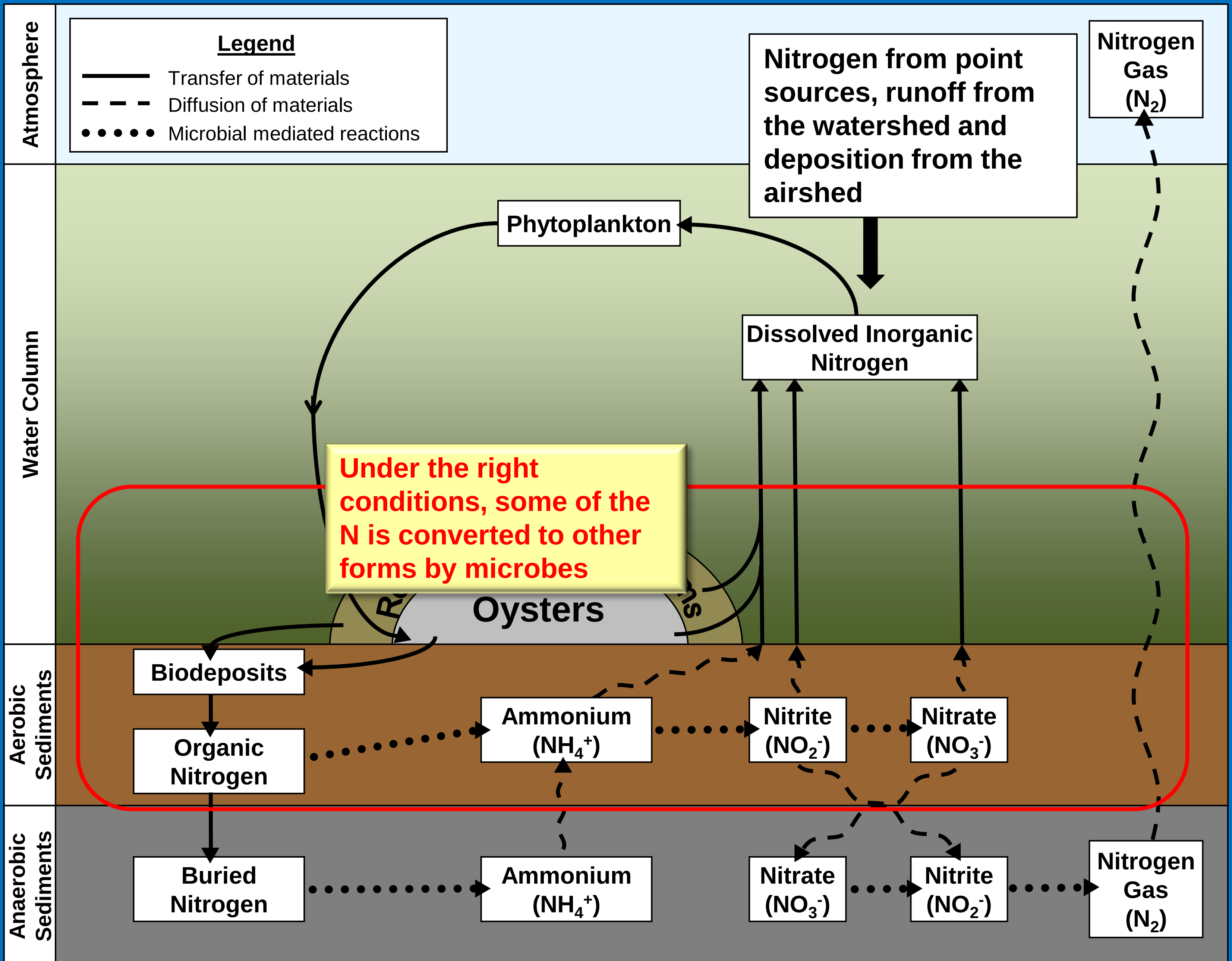

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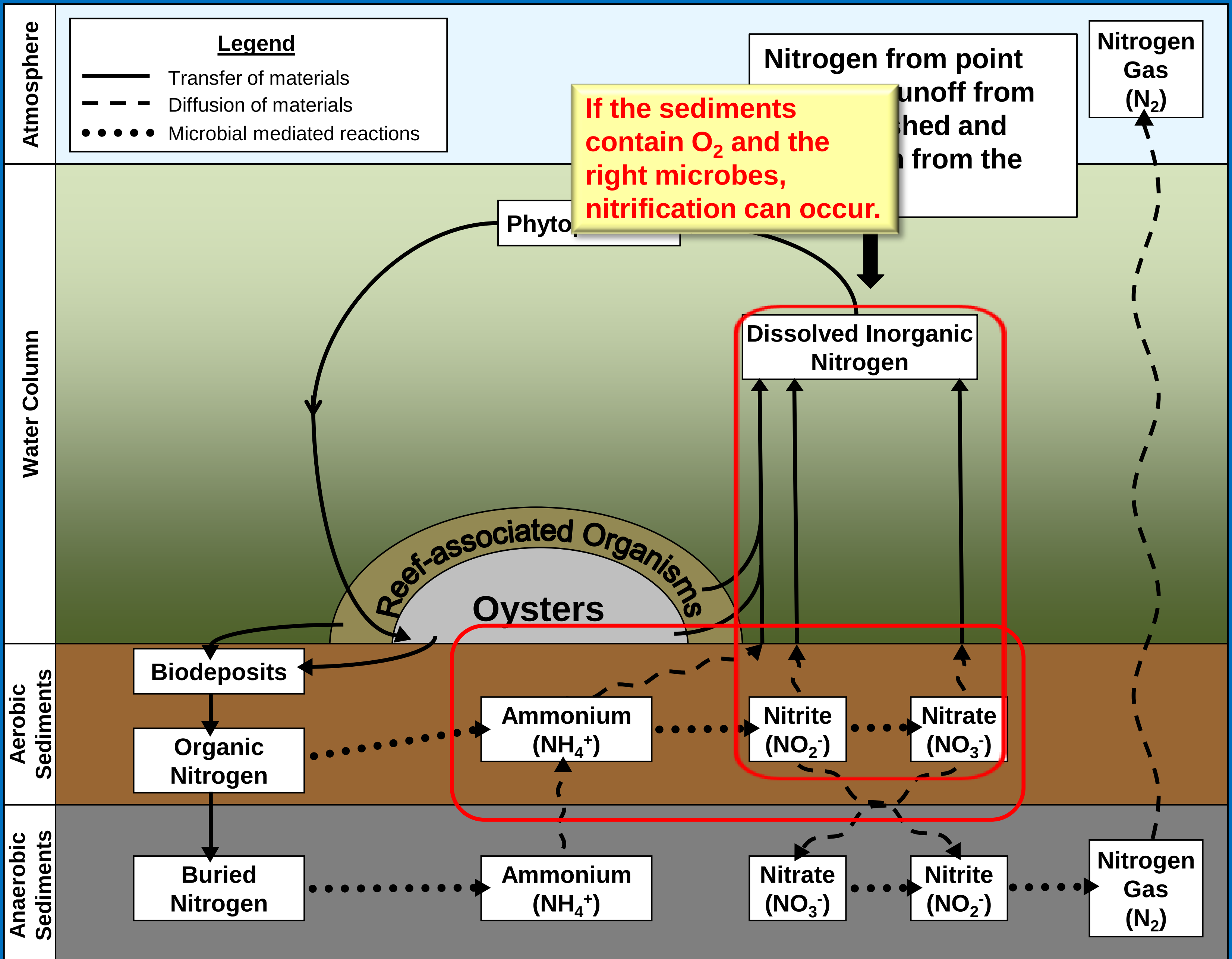

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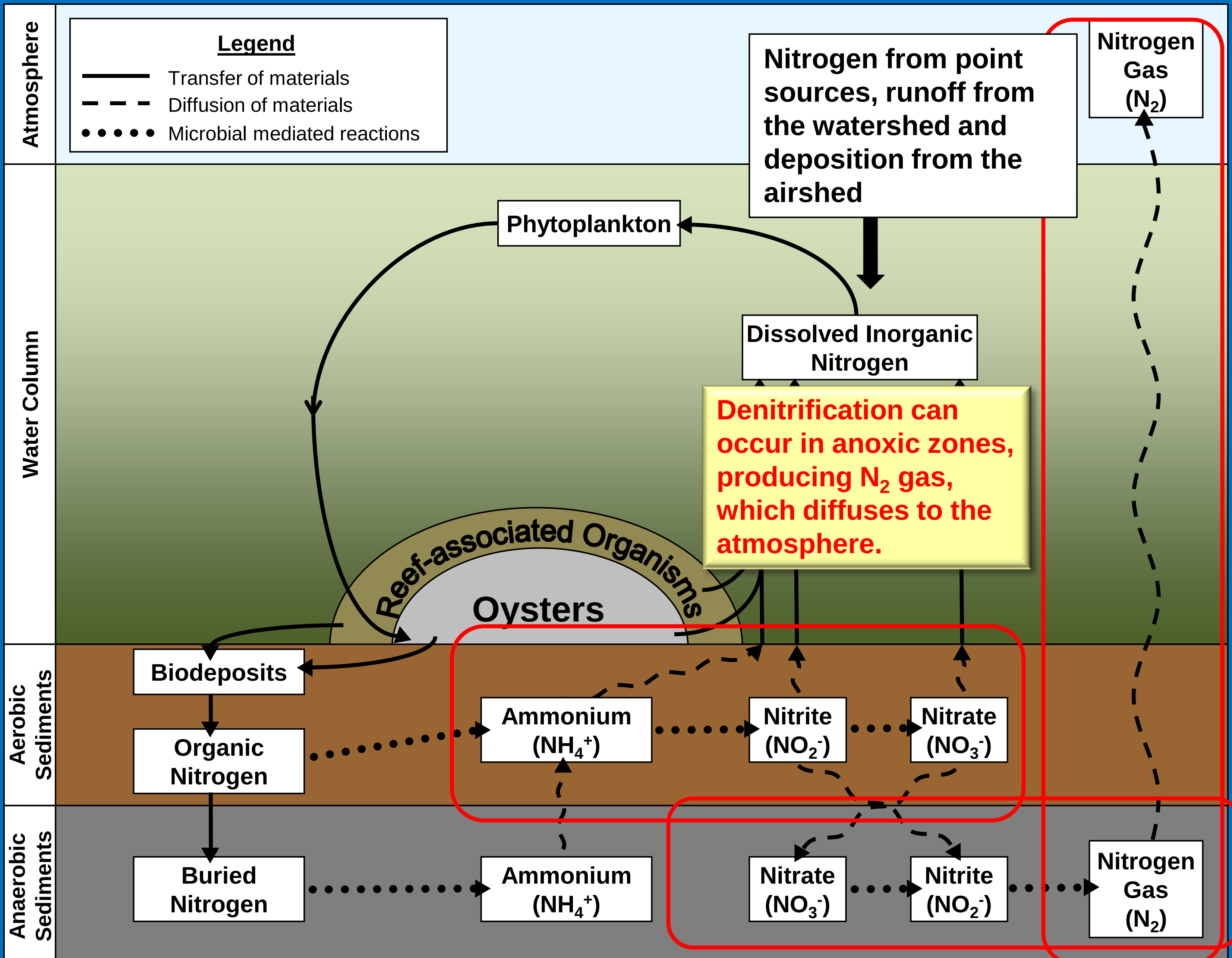

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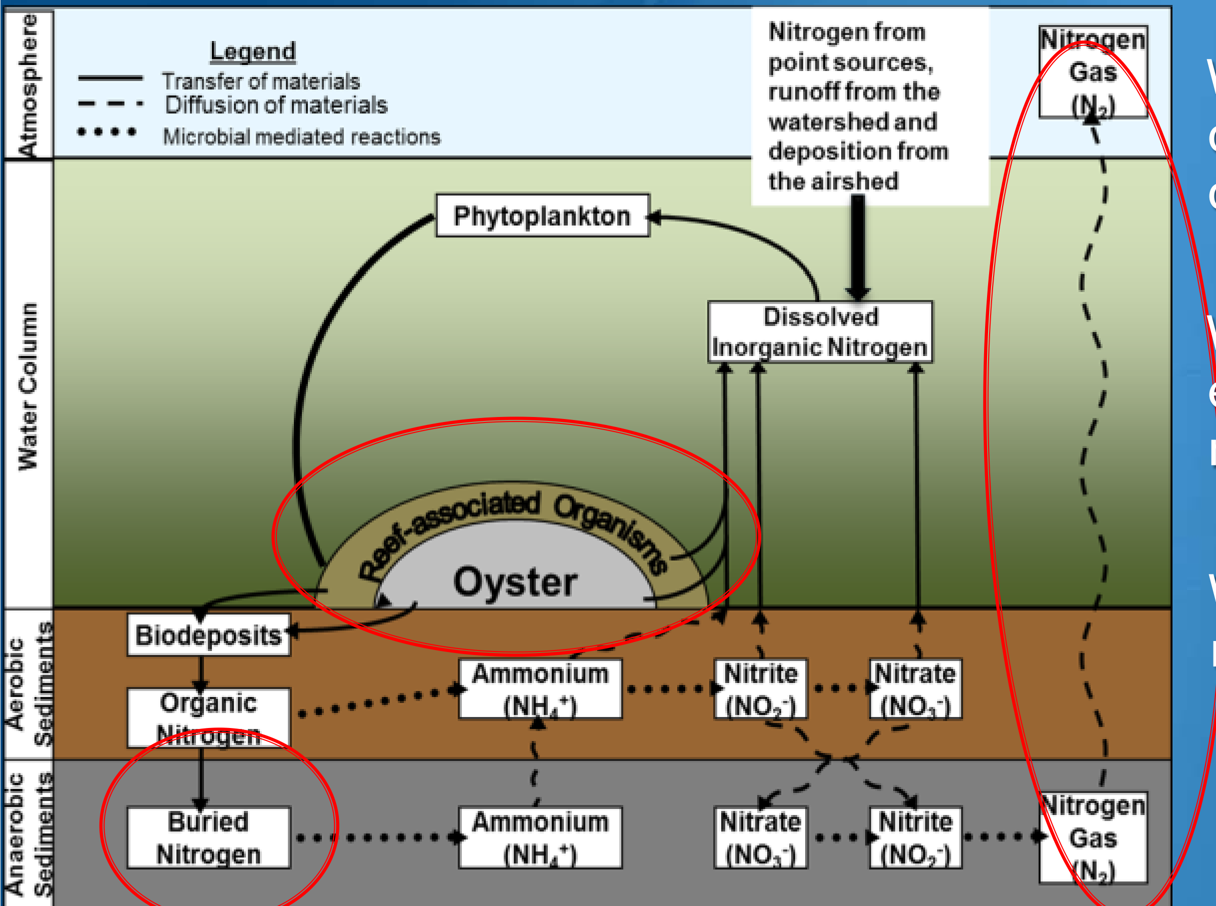
What do we know?



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We have some good numbers on the incorporation into oyster tissues.

We do not have any data on enhanced nutrient burial rates.

We have data from a few recent and ongoing studies.

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Nitrogen content of soft tissue and shell

Source	Location	Conditions	% N
Newell 2004	Choptank River, Chesapeake Bay	Natural oyster reef	Soft tissue: 7.0 Shell: 0.3
Higgins et al. 2011	2 tributaries in Chesapeake Bay	Cultured oysters in floats Oyster density = 286 m^{-2} High and low energy sites	Soft tissue: 7.86 Shell: 0.19
Carmichael et al. 2012	5 estuaries on Cape Cod	Cultured oysters in floats Oyster density = 429 m^{-2} Variation in N loading across watersheds	Soft tissue: 8.6
Carmichael et al. unpublished	2 locations in Mobile Bay	Cultured oysters in cages	Soft tissue: 12
Kellogg et al. 2013	Restored reef in Choptank	Subtidal oyster reef Hatchery-produced spat 2 -7 year-old oysters Oyster density = 131 m^{-2}	Soft tissue: 9.2 Shell: 0.21

Findings:

1) Tight range of %N content in soft tissue (7.00 - 9.27%) and shell (0.19 – 0.3%) in Atlantic estuaries.
2) > 50% of the N is contained in shells
3) Oyster growth rates highly variable. Need harvest biomass.

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What can this do for us in relation to TMDLs?

1 Million market-sized oysters contain about 290 lbs. of N.

Tributary	Load reduction requirements (lbs. N per year)	# oysters harvested to meet 1% of requirement annually
Choptank River, MD	475,682	16 million
Rhode River, MD	4,126	0.14 million
Lynnhaven River, VA	1,409,078	49 million
Mobjack Bay, VA	87,628	3 million

About half of this N is contained in shells, so if the shells are returned to the water, we don't get to count them.

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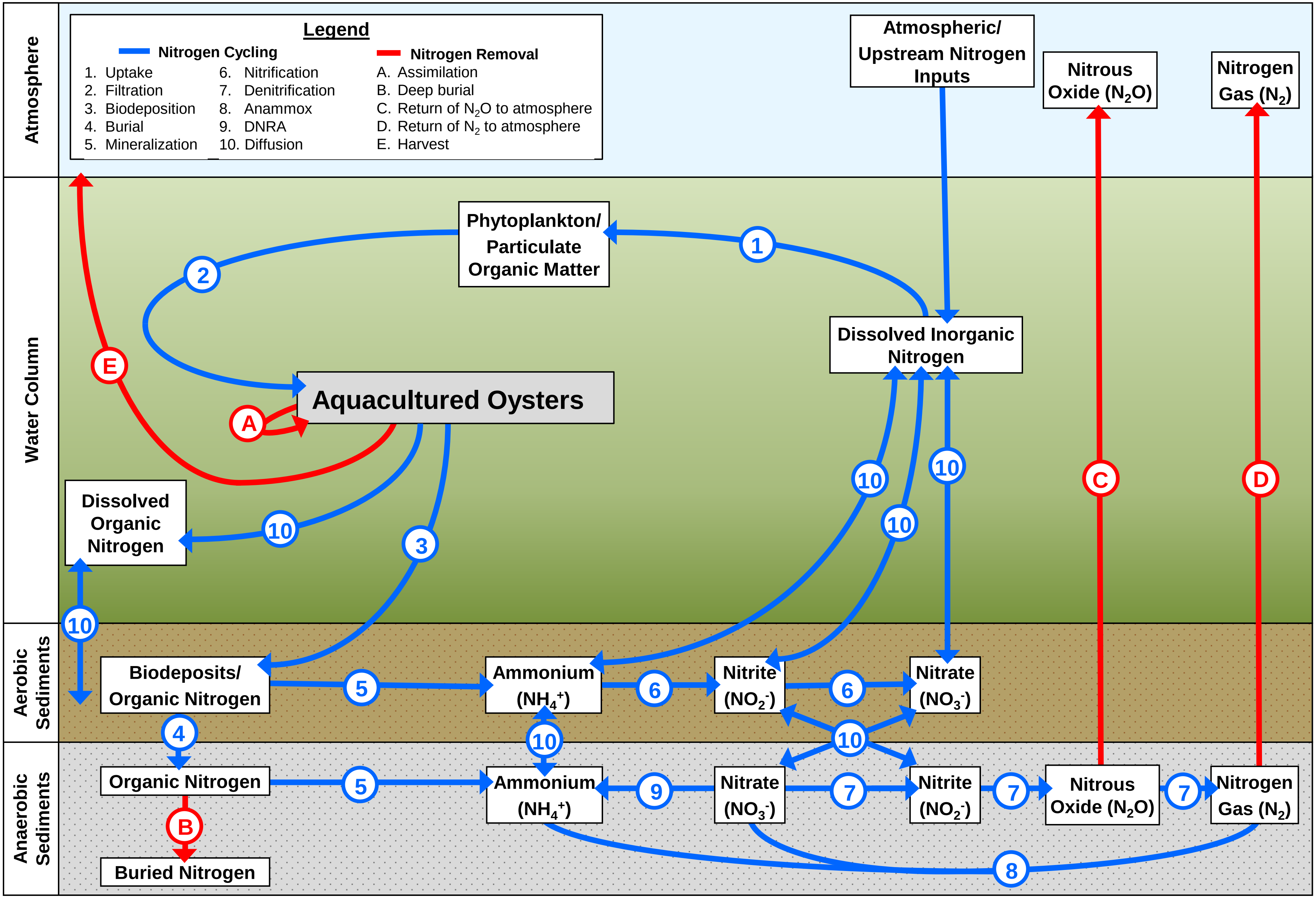
Aquaculture – Aerobic Sediments – Below Euphotic Zone



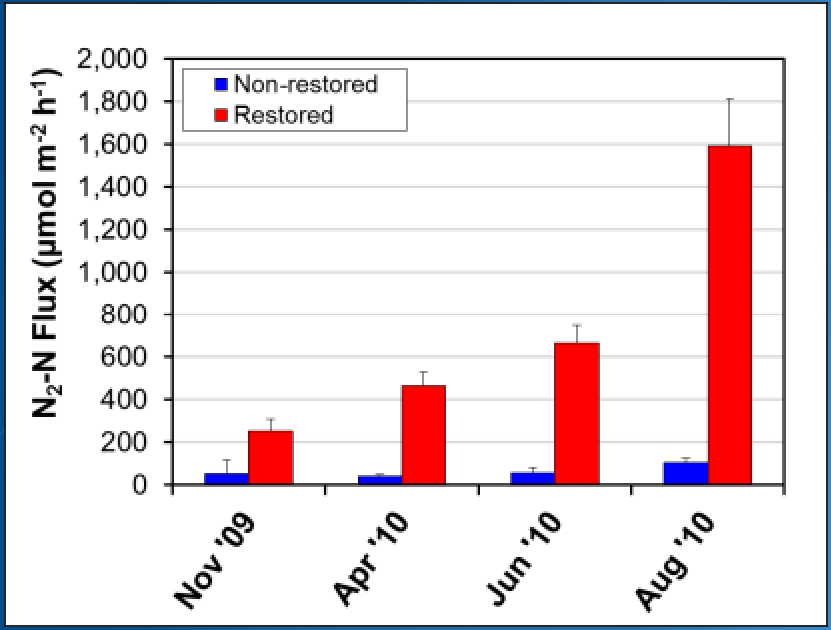
Graphic produced by Lisa Kellogg

So, why be so excited about denitrification?

Kellogg et al. (2013) studied a restored oyster reef in the Choptank River, MD and found:

251 kg N per acre were stored in the tissues and shells of oysters, but this included high densities of oysters up to 7 years old.

225 kg N per acre per year is lost through denitrification.



At this rate, if 23% of the suitable bottom in the Choptank River were restored with comparably healthy oyster reefs, it would equal the entire nutrient reduction target for that tributary.

Wow!

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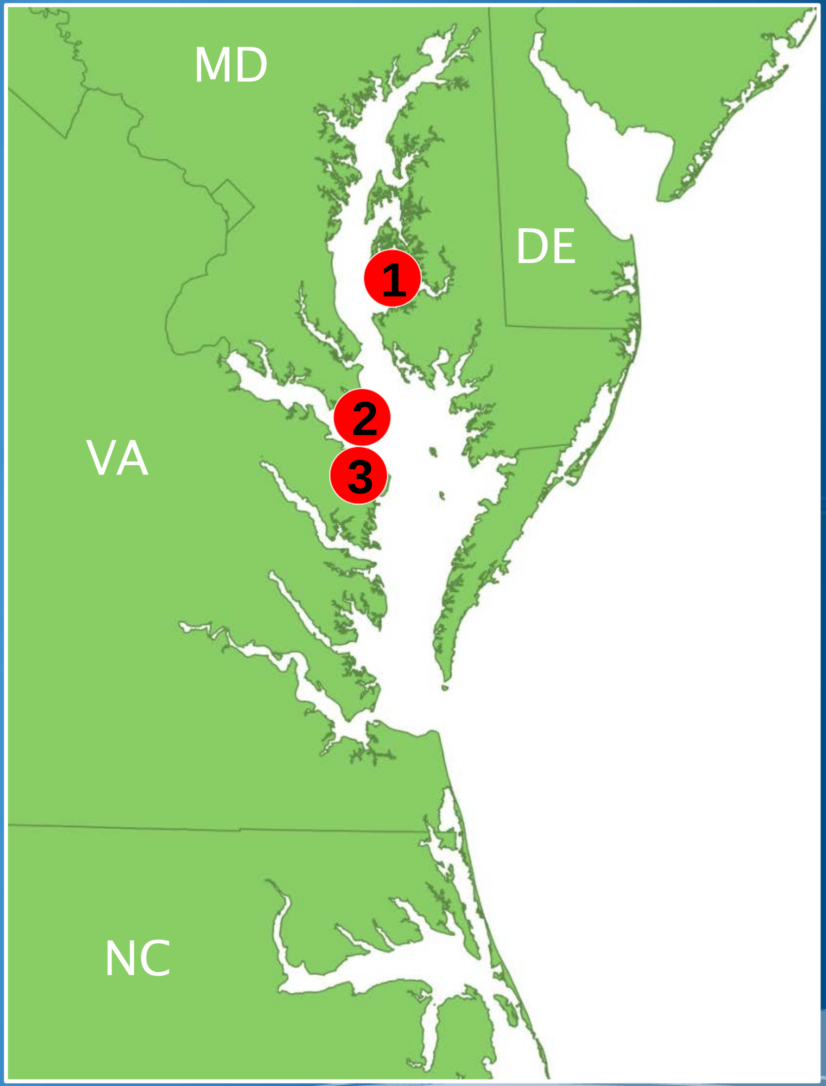
Studies on denitrification at aquaculture sites

1. Choptank River, MD

   Rebecca Holyoke (2008) Ph.D. Thesis, UMD. No increase in denitrification at 4 floating oyster aquaculture sites.

2. St. Jerome Creek, MD
3. Spencer Creek, VA

   Colleen Higgins et al. (2013) No increase in denitrification at 2 floating oyster aquaculture sites



Bottom line: For aquaculture we only get to count the N removed at harvest.

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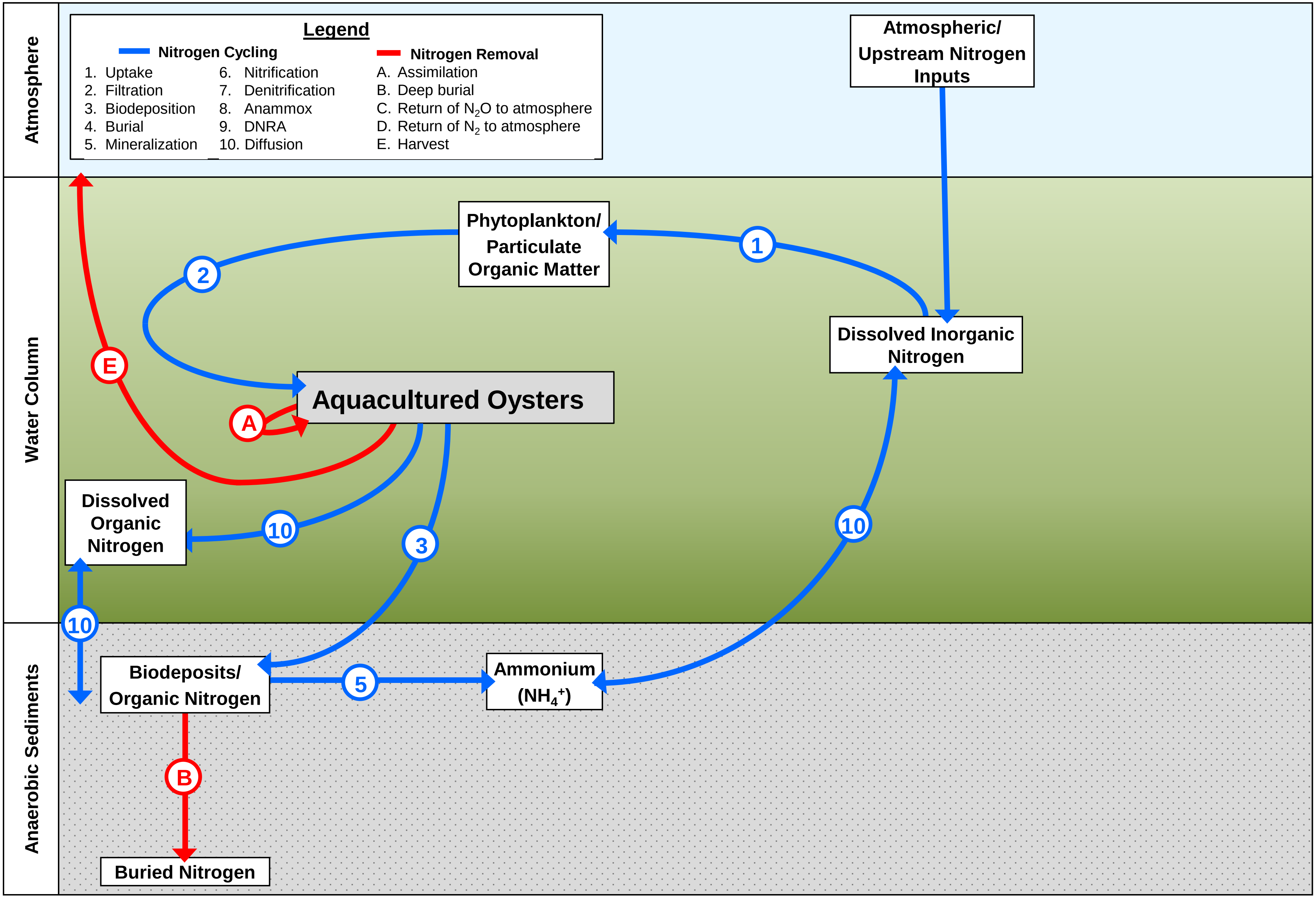
Aquaculture – Anaerobic Sediments



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Studies on denitrification at reef sites

1. Bogue Sound – M. Piehler and Smyth (2011), Symth et al. (2013)

   Intertidal natural oyster reefs

2. Choptank River, MD – Kellogg et al. (2013)

   Restored oyster reef vs. non-restored site. Subtidal (~4 m), below euphotic zone, salinity ~7-11

3. Lynnhaven River, VA – Sisson et al. (2012)

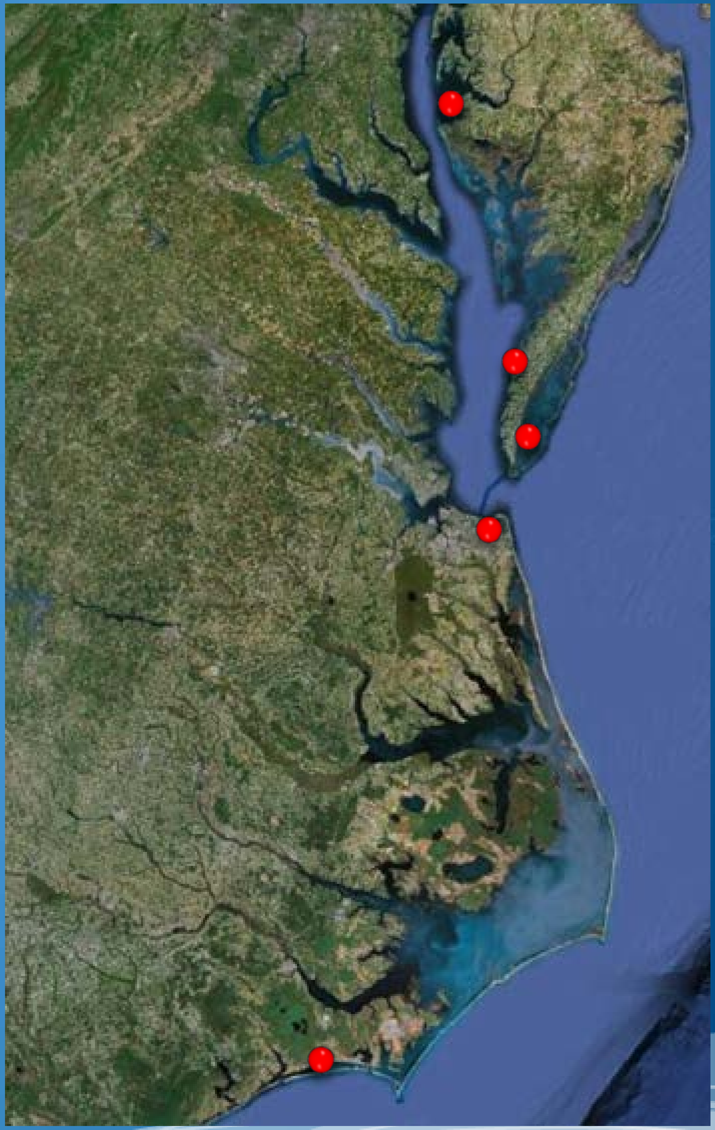
   Existing reefs varying in oyster density; Intertidal and shallow subtidal; within euphotic zone; salinity ~20

4. Onancock Creek, VA – Kellogg et al. (in prep.)

   Replicate experimental reefs of varying oyster density; Shallow subtidal (~1 m); within euphotic zone, salinity ~15

5. VA Coastal Bays, VA – Kellogg et al. (ongoing)

   Replicate experimental reefs of varying oyster density; Intertidal, salinity ~30



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Denitrification – Oyster Reefs

Source	Location	Conditions	Measured value	Values	Comments
Piehler and Smyth 2011	Intertidal oyster reefs in NC	Feb., May, July & Oct. measurements; intertidal mudflat reference sites	N_2 flux in cores containing reef sediments, but no shell.	Reference site --4.5 µmol N m^{-2} d^{-1} Oyster reefs 17.8 µmol N m^{-2} d^{-1}	Denitrification significantly enhanced on intertidal oyster reefs
Kellogg et al. 2013	Subtidal restored reef in the Choptank River	Oyster density – 131 m^{-2}	N2 flux in chambers with reef materials	Reference site 39-105 µmol N m^{-2} d^{-1} Oyster reefs 252-1592 µmol N m^{-2} d^{-1}	Denitrification greatly enhanced on restored reef
Sisson et al. 2010	Natural and restored reefs in Lynnhaven River. Intertidal & shallow subtidal	7 small reefs with varying oyster density: 47 – 576 m^{-2}	N_2 flux in chambers with reef materials	Reference site: 0 µmoles m^{-2} hr^{-1} Reef sites: 0 -324 µmoles m^{-2} hr^{-1}	Positive relationship between denitrification and total oyster biomass
Kellogg et al. (in prep.)	Shallow subtidal experimental oyster reefs	Experimental oyster reef densities = 0 to 250 oysters m^{-2}	N_2 flux in chambers with reef materials	Reference site: 65 µmoles m^{-2} hr^{-1} Reef sites: 298-800 µmoles m^{-2} hr^{-1}	Positive, asymptotic relationship between oyster soft tissue biomass and denitrification
Kellogg et al. (on-going study)	Intertidal experimental oyster reefs	Experimental oyster reef densities = 0 to 250 oysters m^{-2}	N_2 flux in chambers with reef materials	Reference site: 87-123 µmoles m^{-2} hr^{-1} Reef sites: 139-814 µmoles m^{-2} hr^{-1}	Weak relationship between DNF rates and oyster biomass. Lower than subtidal rates.

Findings: 1) DNF rates on oyster reefs are generally greater than those at reference sites.
2) DNF rates in intertidal reefs are lower and more variable than on subtidal reefs.

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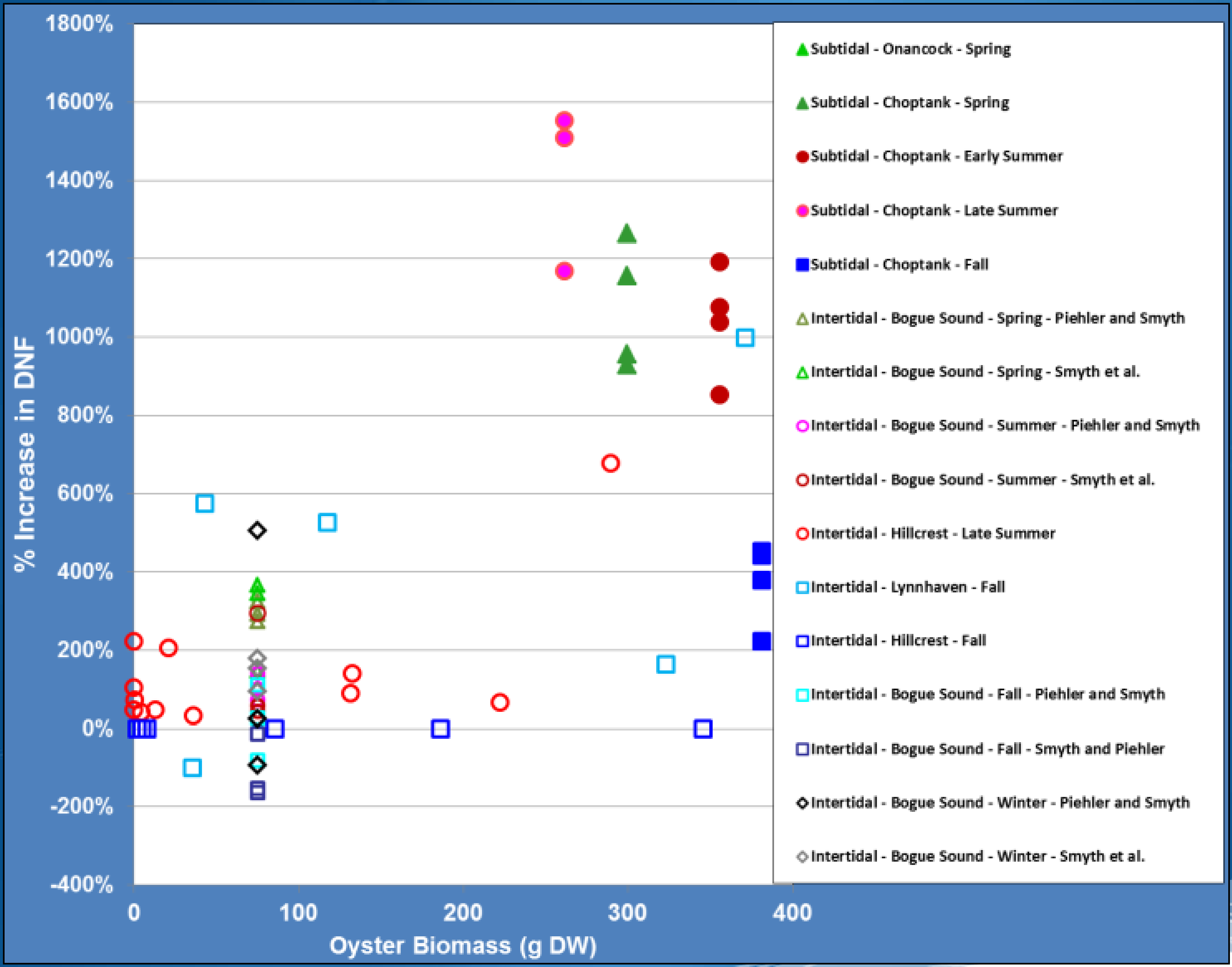
Meta-analysis: Increase in DNF with Oyster Biomass



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From the DRAFT STAC Report:

Finding 6: Denitrification rates measured for oyster reefs typically exceed background levels in adjacent non-structured environments, with most, but not all, reefs exhibiting rates of denitrification that are 1.5- to 14-fold increases above reference sites.

However, several factors including oyster biomass, tidal exposure, depth relative to the euphotic zone, and other unknown environmental factors affect these rates in ways that have not yet been fully quantified.

So, can shellfish aquaculture really provide nutrient reduction in Chesapeake Bay?

Yes, but at this point we can only count the nutrients actually removed at harvest from aquaculture.

How and where we do aquaculture matters.

Under some conditions, shellfish aquaculture may actually lead to locally elevated nutrient levels.

Inclusion of shellfish aquaculture in the TMDL process will require attention to the details, monitoring and further research.

If we wish to use this as a strategy, we need to be realistic about the magnitude of the potential effects relative to the goal in a particular tributary.

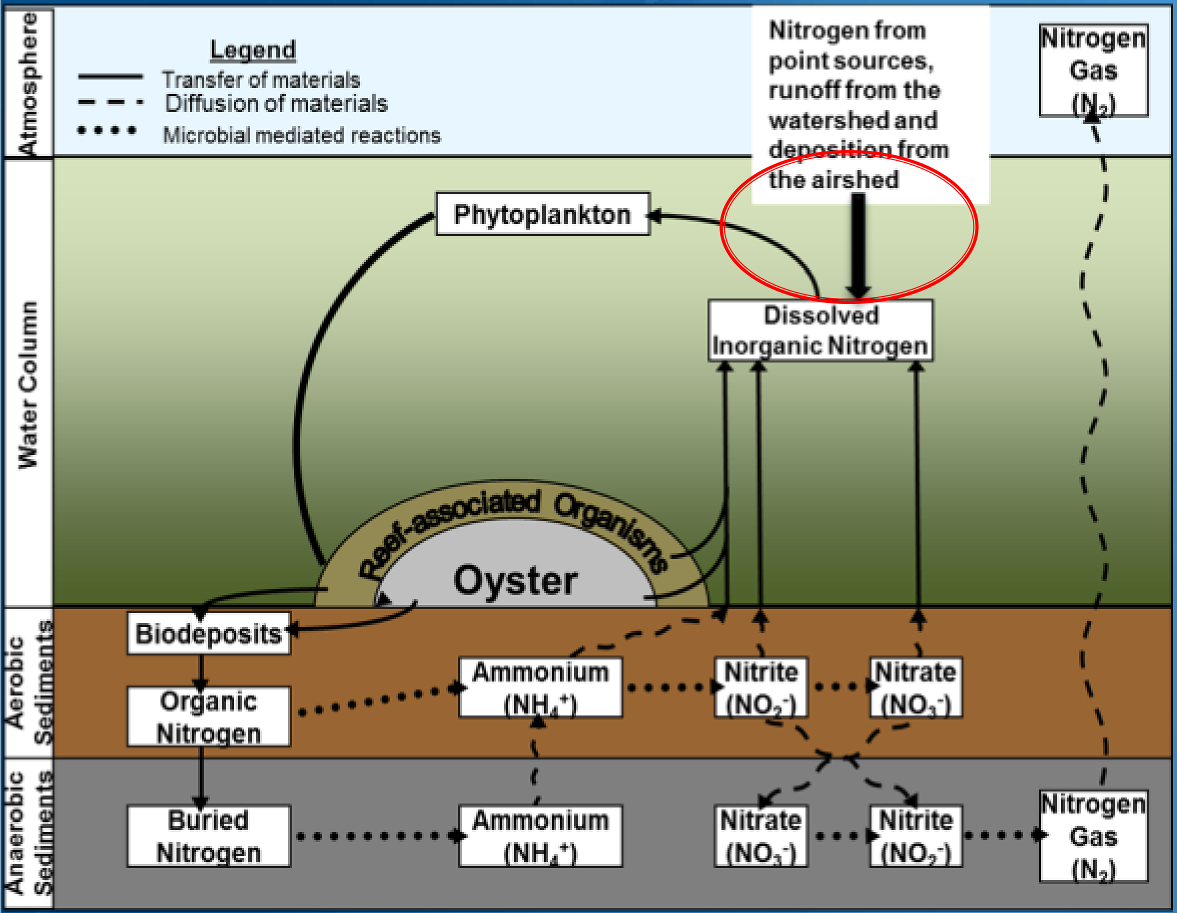
What about oyster sanctuaries? Can they provide nutrient reduction through denitrification?

Yes, we have good evidence that they generally enhance denitrification rates.

But, the magnitude of this effect is highly variable and we do not entirely understand the cause of this variation.

Where we do have some estimates, it is important that we put the potential effect of oysters into context with the magnitude of the problem.

When we do get better numbers how do we use them?



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TMDL’s are about reducing loads to the water.

Oysters have the ability to enhance the capacity of the system to deal with those loads once they have reached the water.

The logical approach is to re-run the models with the effect of oysters and establish new load reduction targets.

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Thank you.
Questions?

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Oyster aquaculture in Chesapeake Bay

Floating trays

Rack and bag

Spat-on-shell

Bottom cages

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Effects of large-scale shellfish culture on nutrients

Cherrystone Inlet

37 shellfish leases occupy 1/3 of the bottom.

~100 M cultured clams

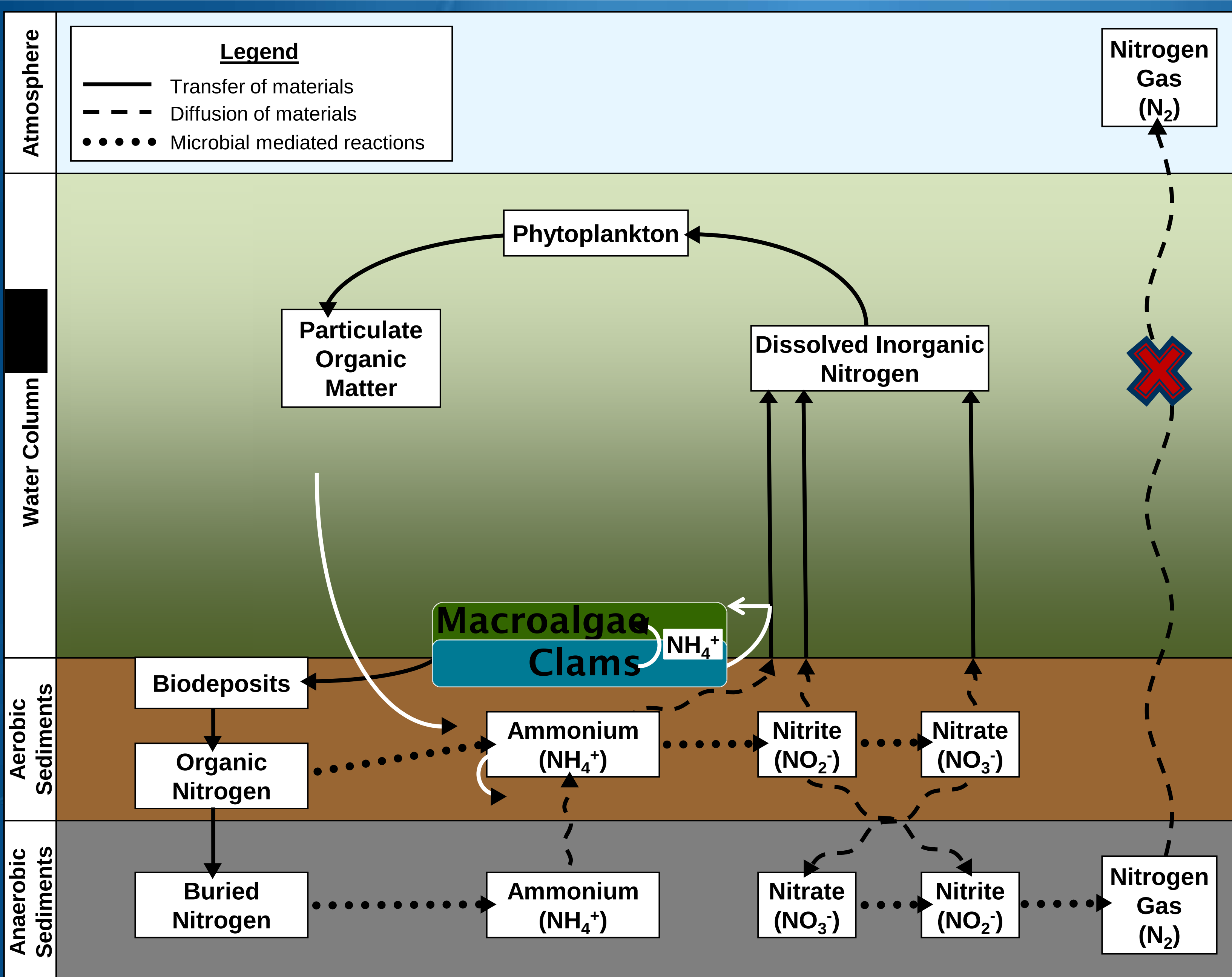
In the summertime can filter ~86% of the tidal exchange volume.

The harvesting of clams removes significant amounts of N.

Effects of large-scale shellfish culture on nutrients

Filtration by the clams enhances water clarity.

Large blooms of macroalgae, or seaweed, on the nets.



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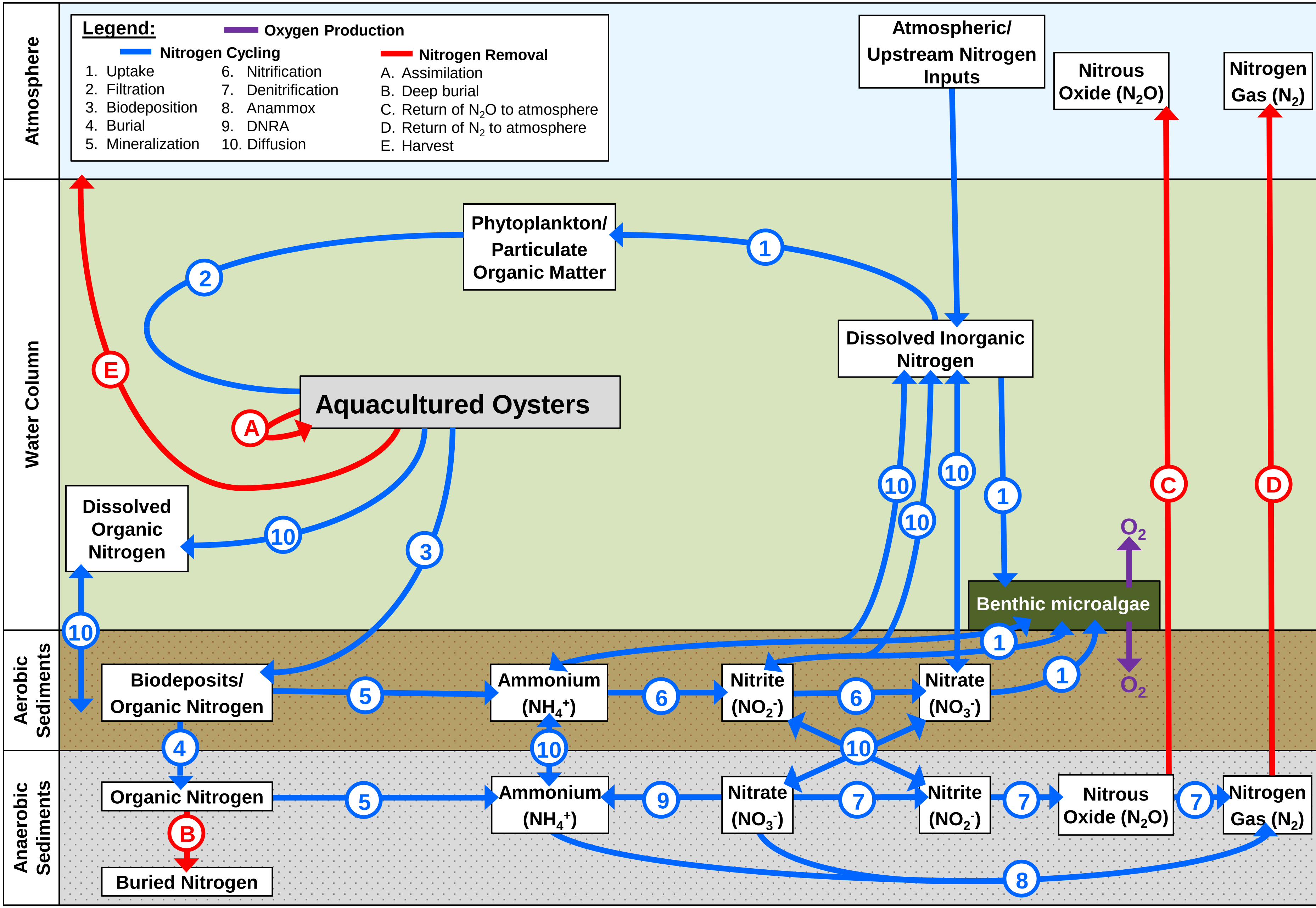
Oyster Aquaculture – Aerobic Sediments – Within Euphotic Zone



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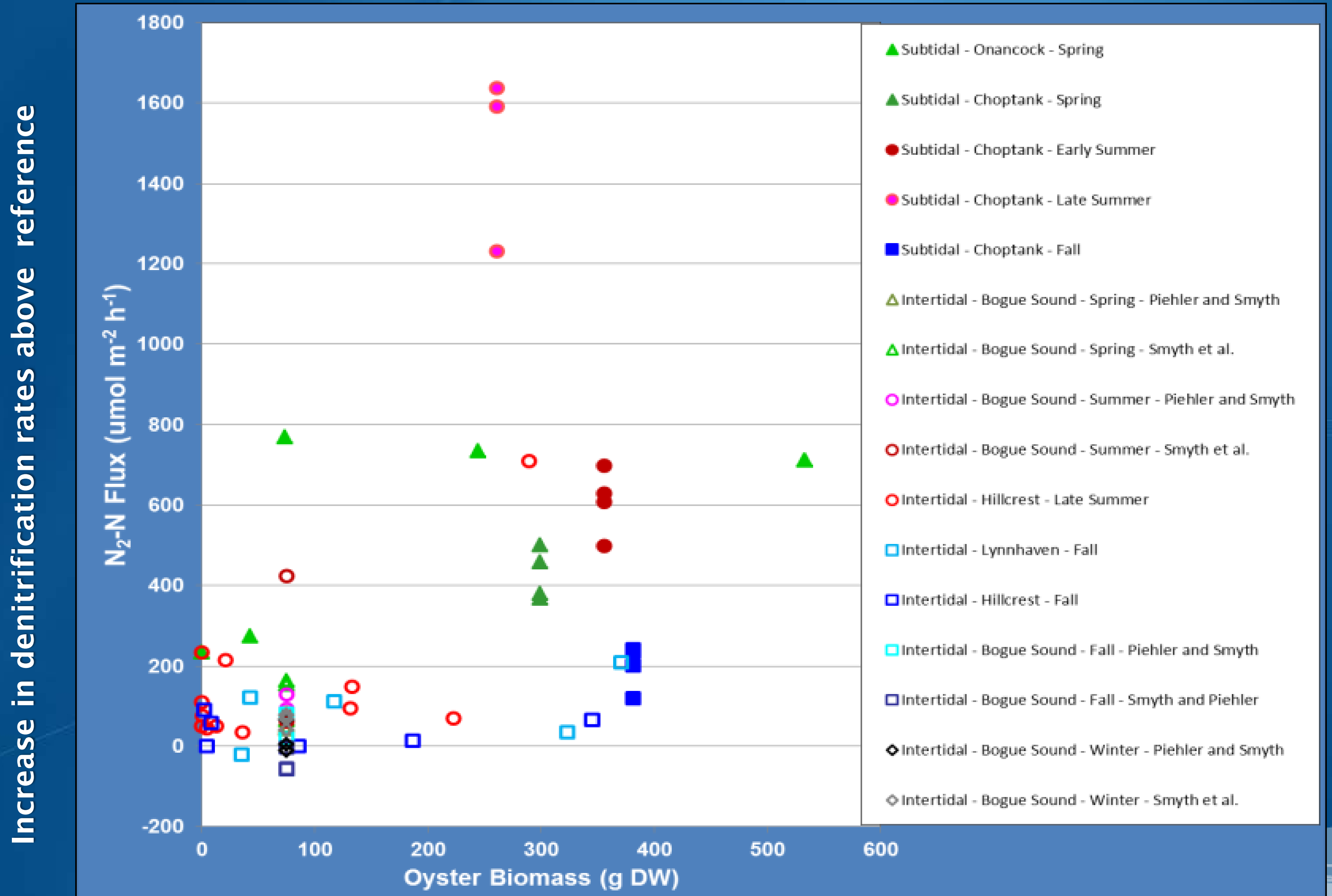

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What can this do for us in relation to TMDLs?

Assuming the highest rates measured in the Lynnhaven in the fall provide an estimate of average annual rates and that we can achieve nearly continuous coverage by oysters.

Tributary	Load reduction requirements (lbs. N per year)	# oysters harvested to meet 1% of requirement annually	# acres to meet 1% of annual requirement through DNF
Choptank River, MD	475,682	16 million	
Rhode River, MD	4,126	0.14 million	
Lynnhaven River, VA	1,409,078	49 million	62
Mobjack Bay, VA	87,628	3 million	