Diatom-based applications for assessment and monitoring of New Jersey coastal wetlands condition

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Acknowledgements

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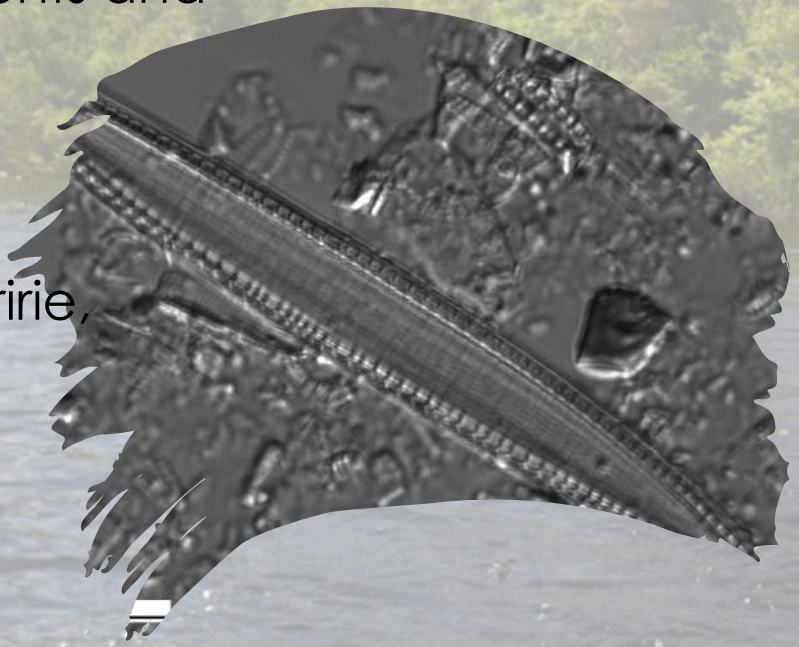
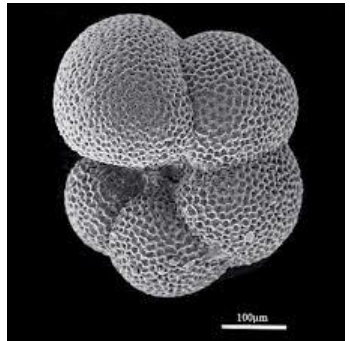
- DSR management and funding
- EPA , USGS funding
- My supervisors (B. Cumming, Y. Paririe, L & B. Ionesi)

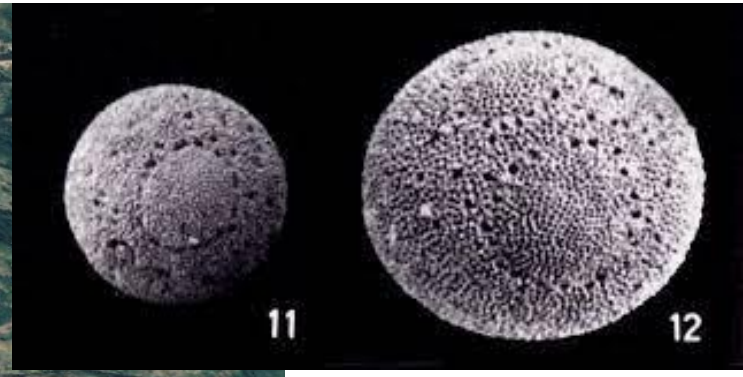


My connections to the microscopic world

- Microfossils - biostratigraphy and paleoecology

- Foraminifera - Carpathian mountains and Cheliff Basin - N Africa





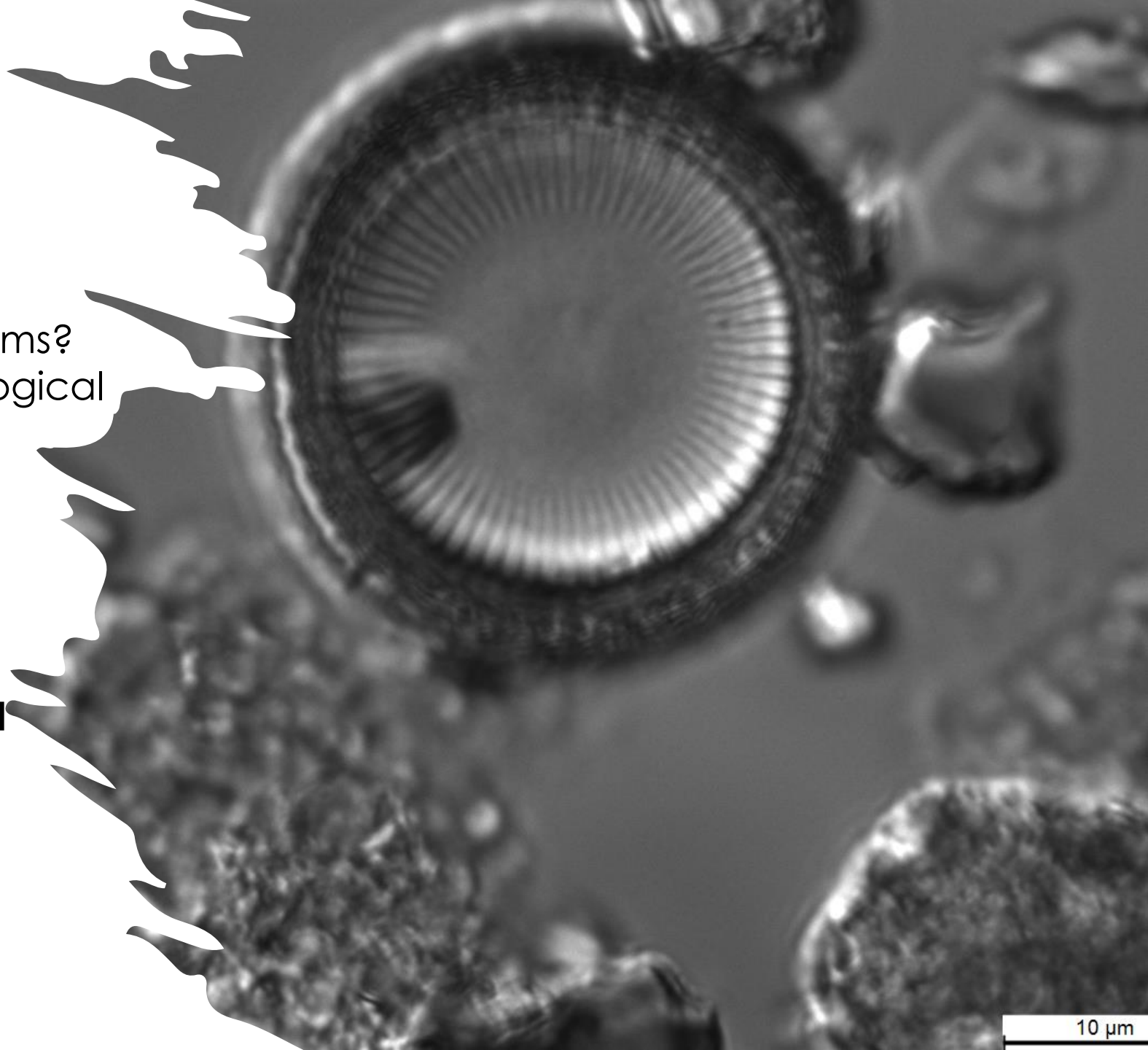
Define Badenian stage in Carpathians piedmont (central Europe =- Parathetys) vs Tortonian (Mediterranean Basin - Tethys)

Tortonian / Messinian stratigraphy and paleoecology in the Cheliff Basin diatomites

Diatoms: Climate and Fire dynamics

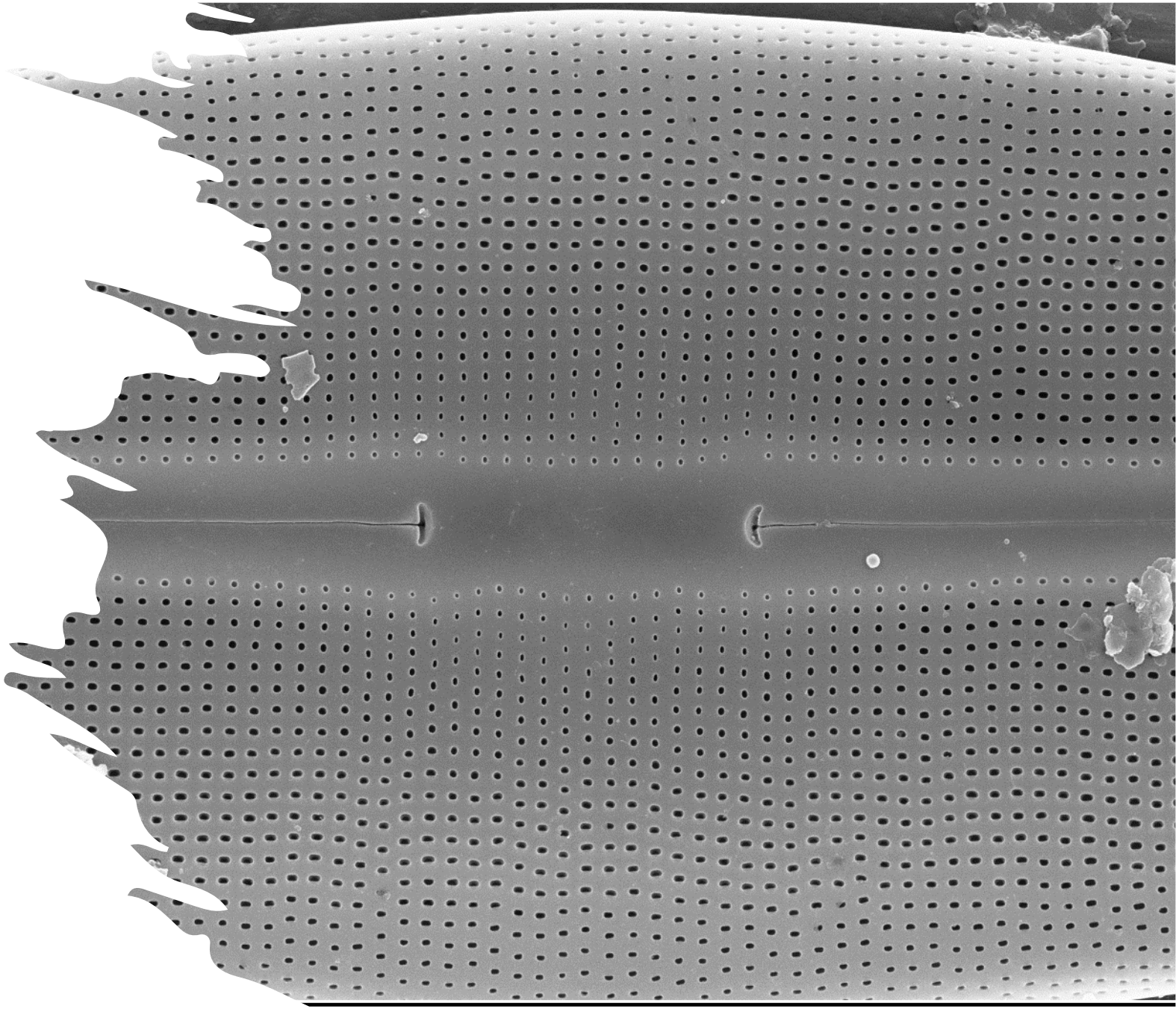
Summary

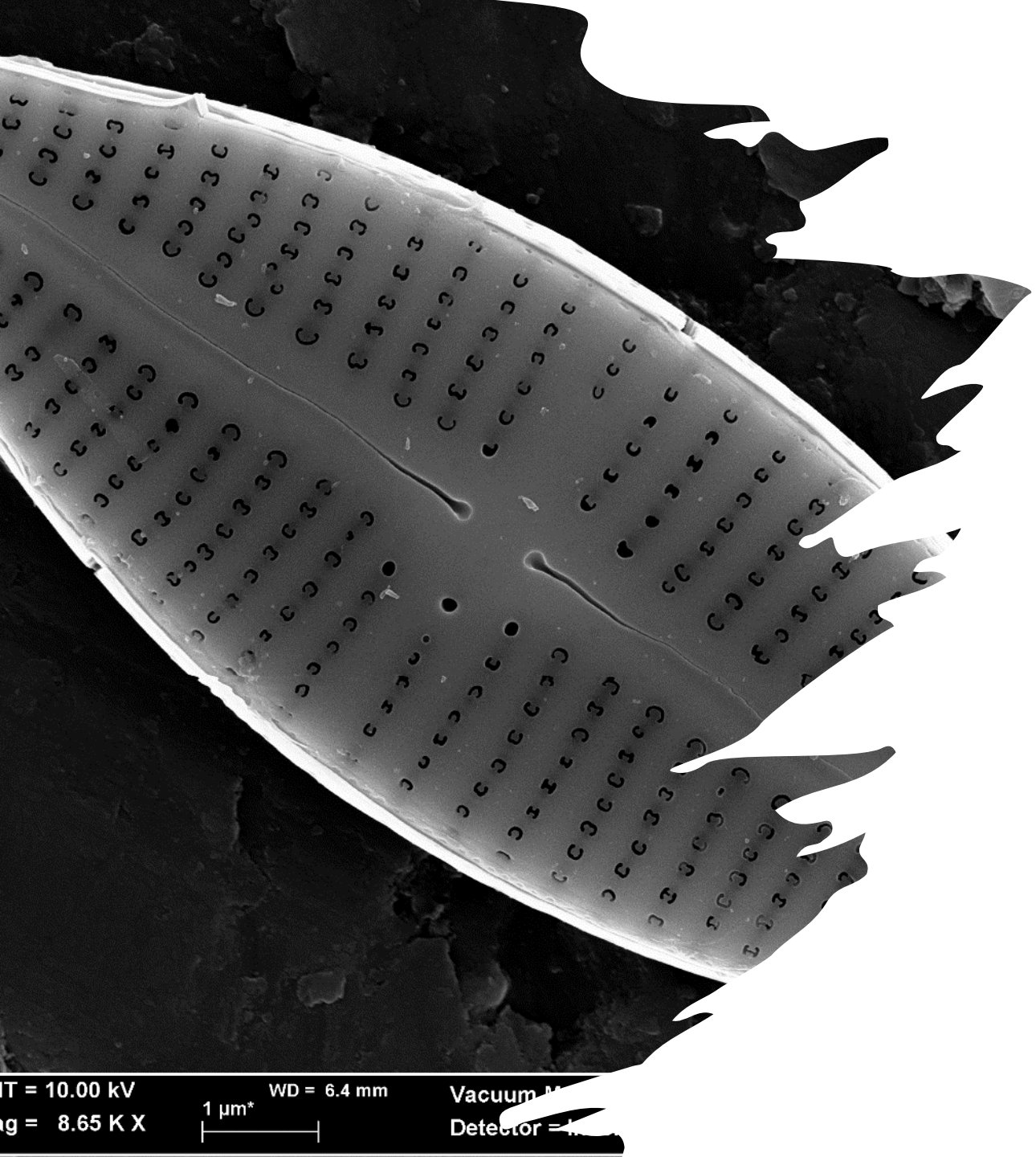
- **Background** -What are diatoms? Why diatoms are great ecological indicators
- **How are diatoms used in environmental reconstructions**
- **Diatom-based applications for assessment, monitoring and restoration potential in NJ**



What are diatoms?

- Single celled algae enclosed in silica shells
- Photosynthetic
- Cell walls made of transparent, opaline silica
- Ornamented by intricate and striking patterns
- Microscopic - 2 µm to 500 µm (= 0.5 mm)

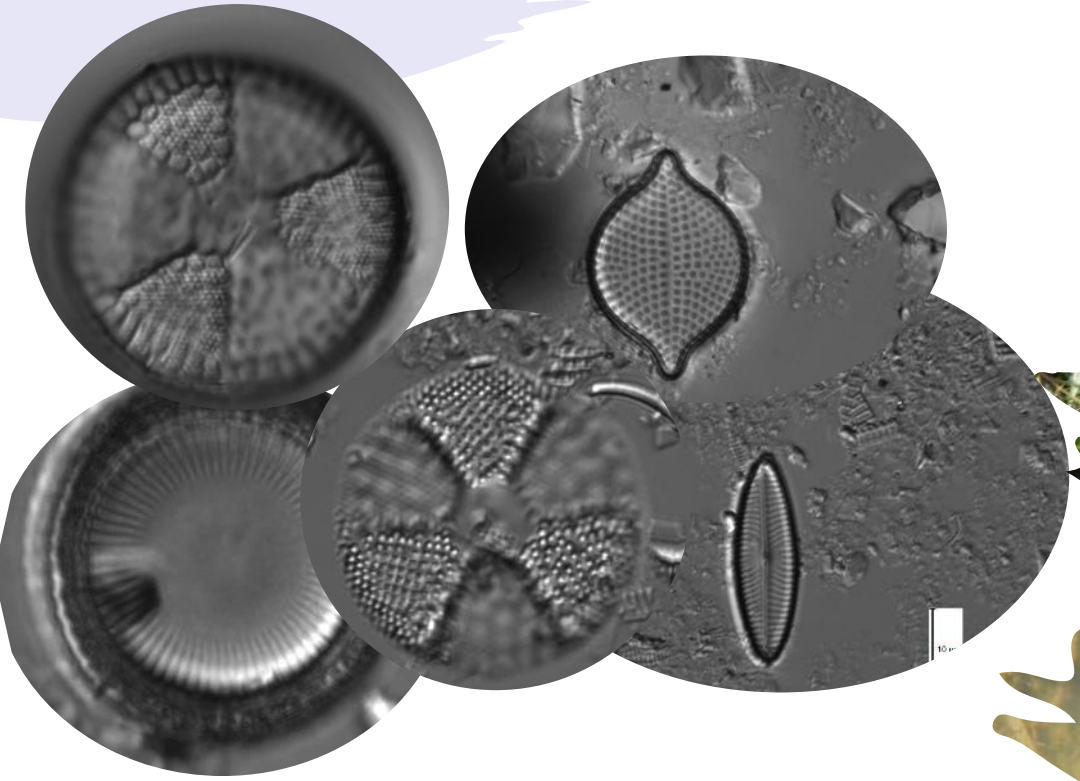




Why are diatoms important?

- Produce 20-30% of earth oxygen
- Remove CO2 from atmosphere, convert to organic C (sugar) and release O2
- Important source of food to the food web due to long chain fatty acids
- 20K-2M species, every year new species are discovered
- Tell us the condition of the environment
- Can serve as surrogate to instrumental measurements
- Practical applications for environment protection

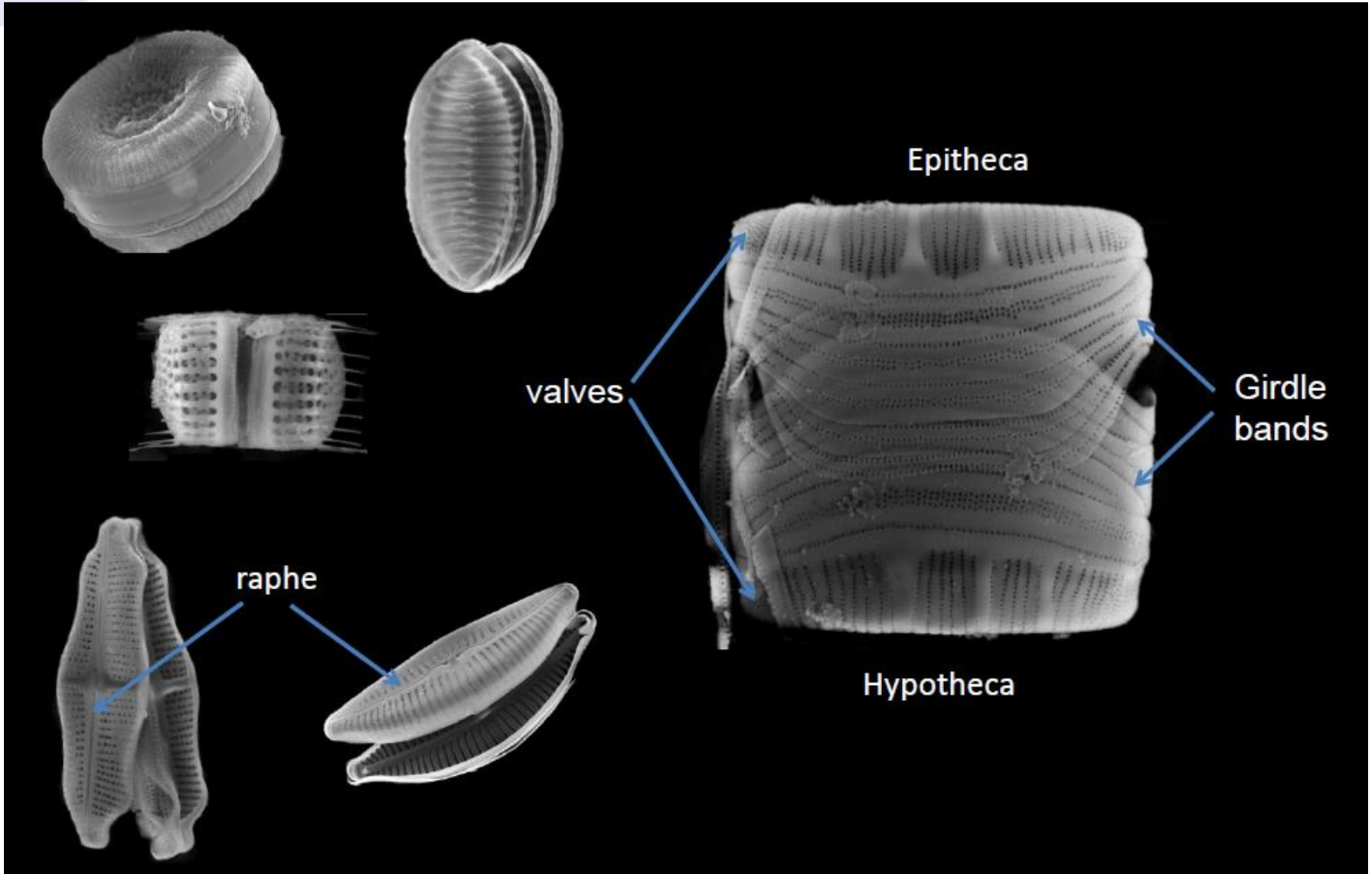
Small in size but big in function!

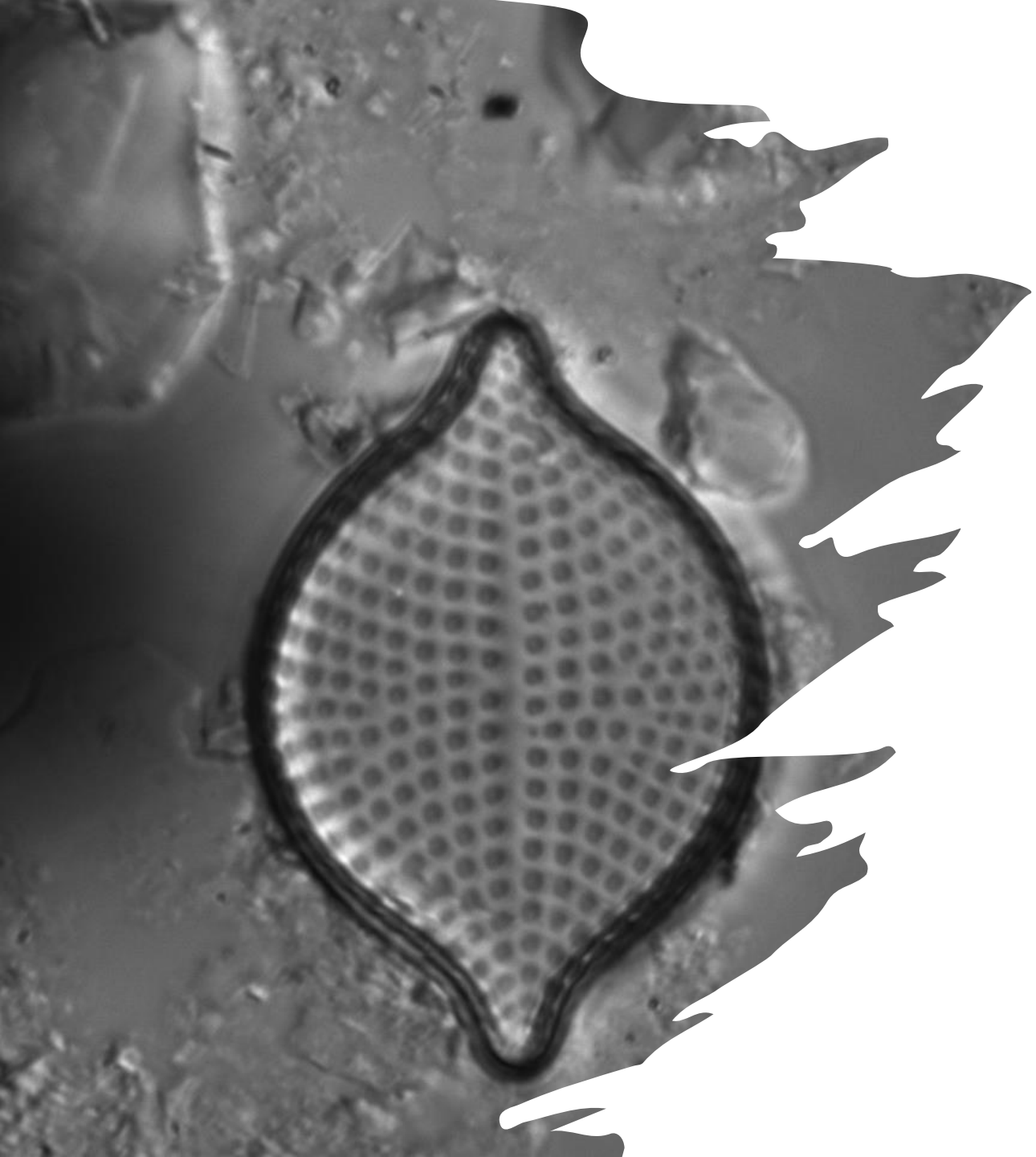


- Diatoms in Barnegat Bay salt marshes

Photos curtesy M. Potapova

Diatom skeleton: frustule





Why diatoms are great environmental indicators

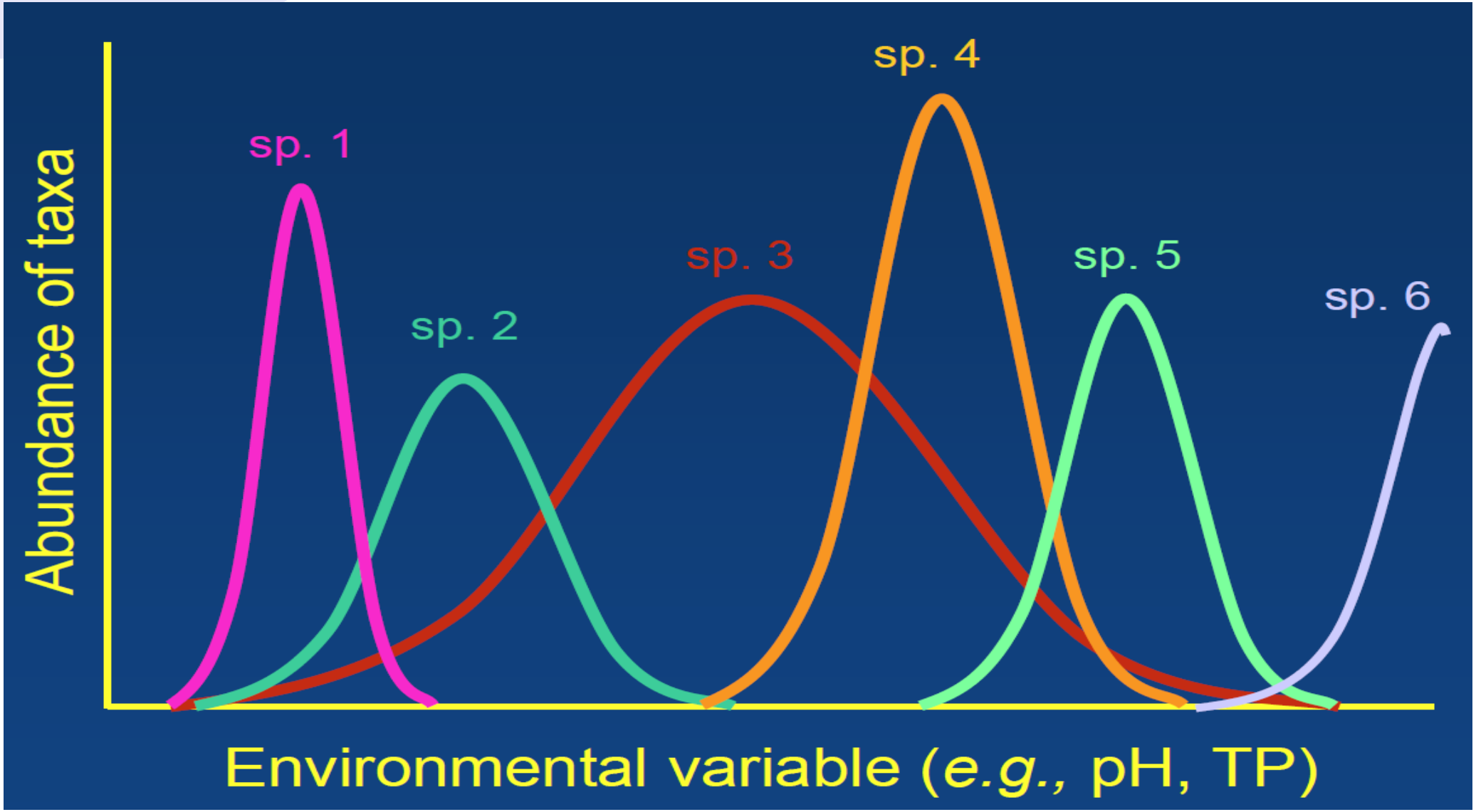
- 1) Species are highly sensitive to environmental factors with specific optima and tolerance
- 2) Their silica shells preserve and accumulate in sediment deposits reflecting the environmental conditions before death

Diatoms and the environmental calibration

- Diatoms ecological response needs to be quantified
- Requires sampling of both diatom and environmental data, tandem samples for same site / time
- In NJ relationships of diatoms to nutrient concentrations, salinity, sediment N and C, tidal inundation, pollution factors have been or are currently being investigated

Photo curtesy Brittany Wilburn

The calibration step

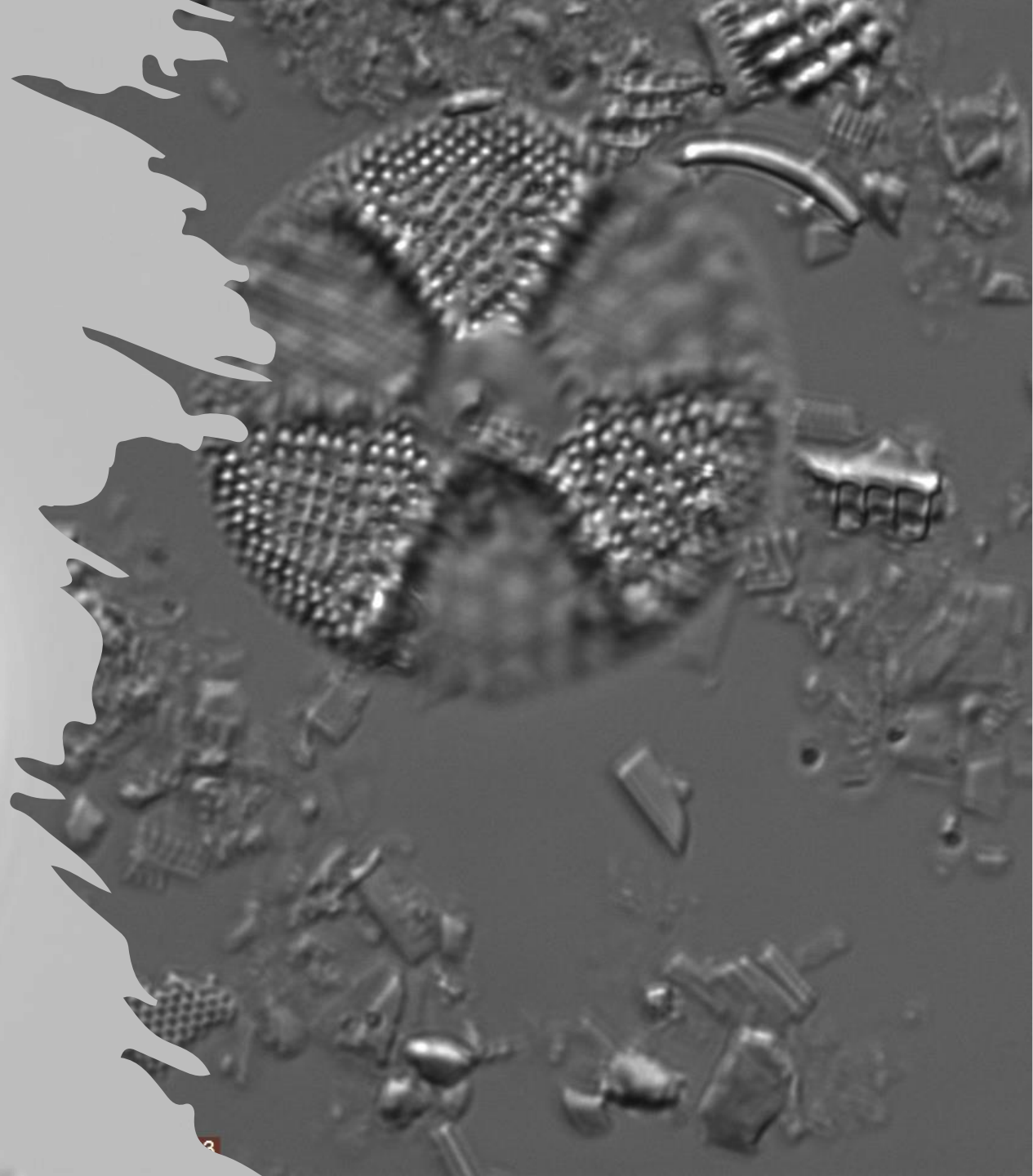


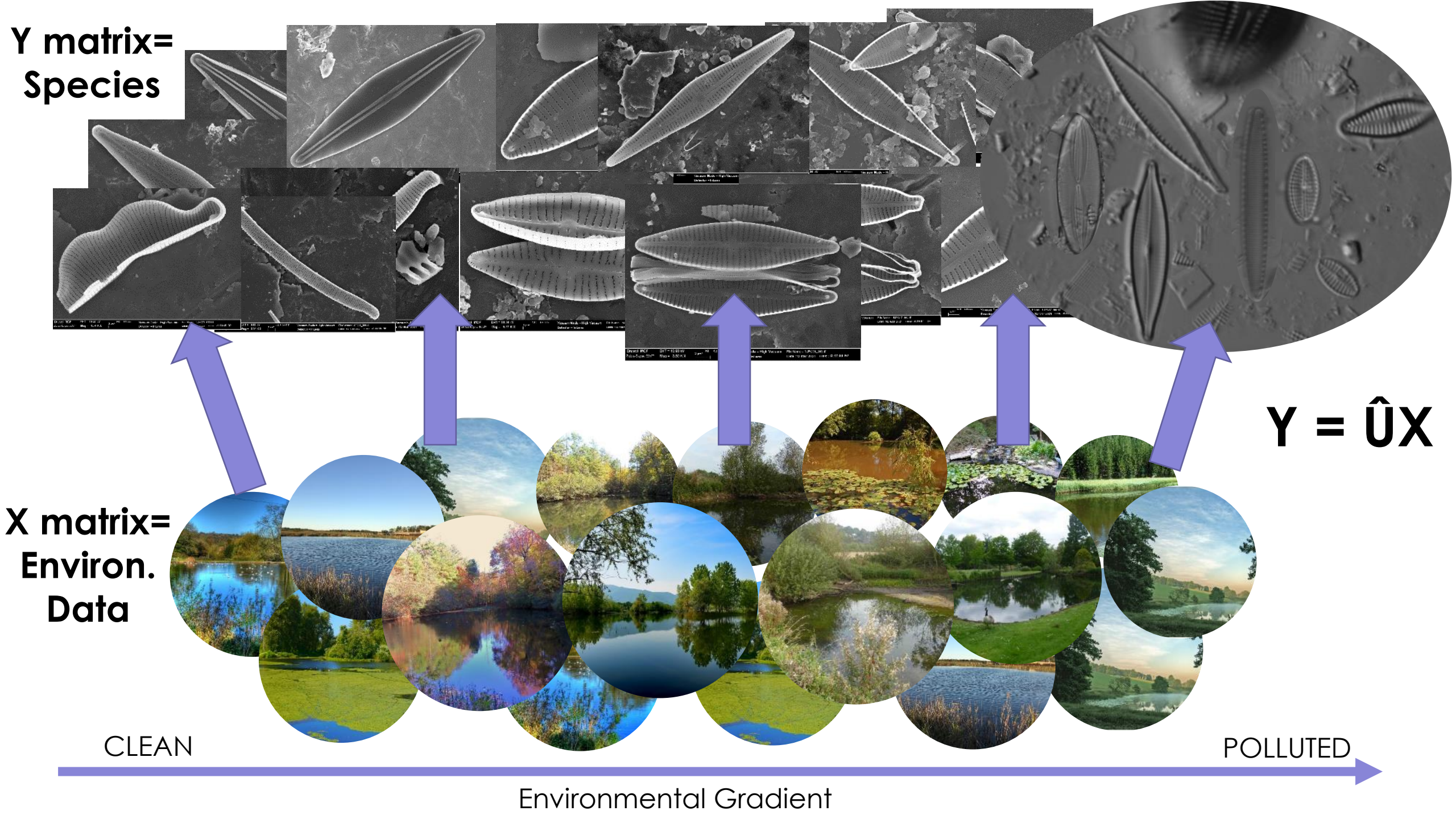
Slide curtesy J. Smol

The calibration step

- Two factors can ensure the success of this step:
- 1) sample a wide gradient of environmental parameter of interest
- 2) species identification (taxonomy)

- Requires two data sets one for the biological data and one for the environmental data



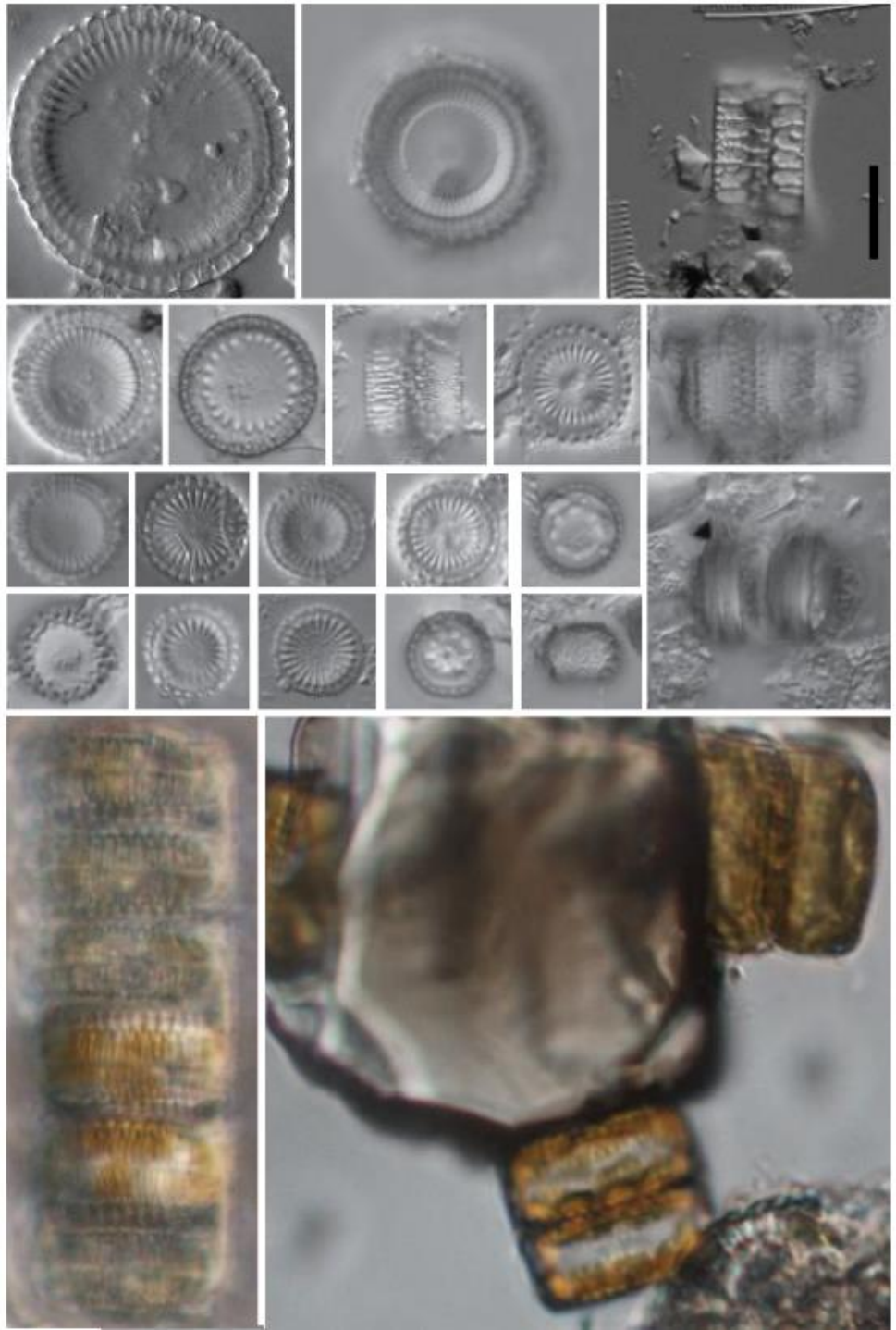

Y matrix=
Species
Y = ÛX
X matrix=
Environ.
Data
CLEAN
POLLUTED
Environmental Gradient

Diatom Voucher floras

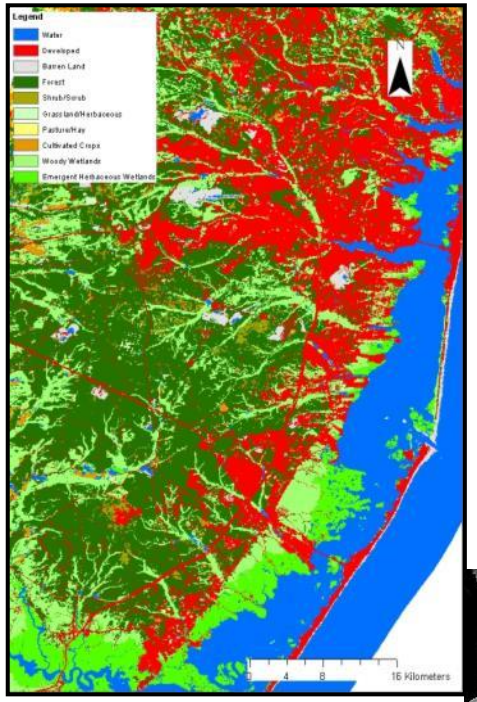
- Voucher floras provide species identification and illustration that can be used to ensure taxonomic consistency
- NJ coastal wetlands voucher flora (DSR website)
  Diatom Flora of the New Jersey Coastal Wetlands

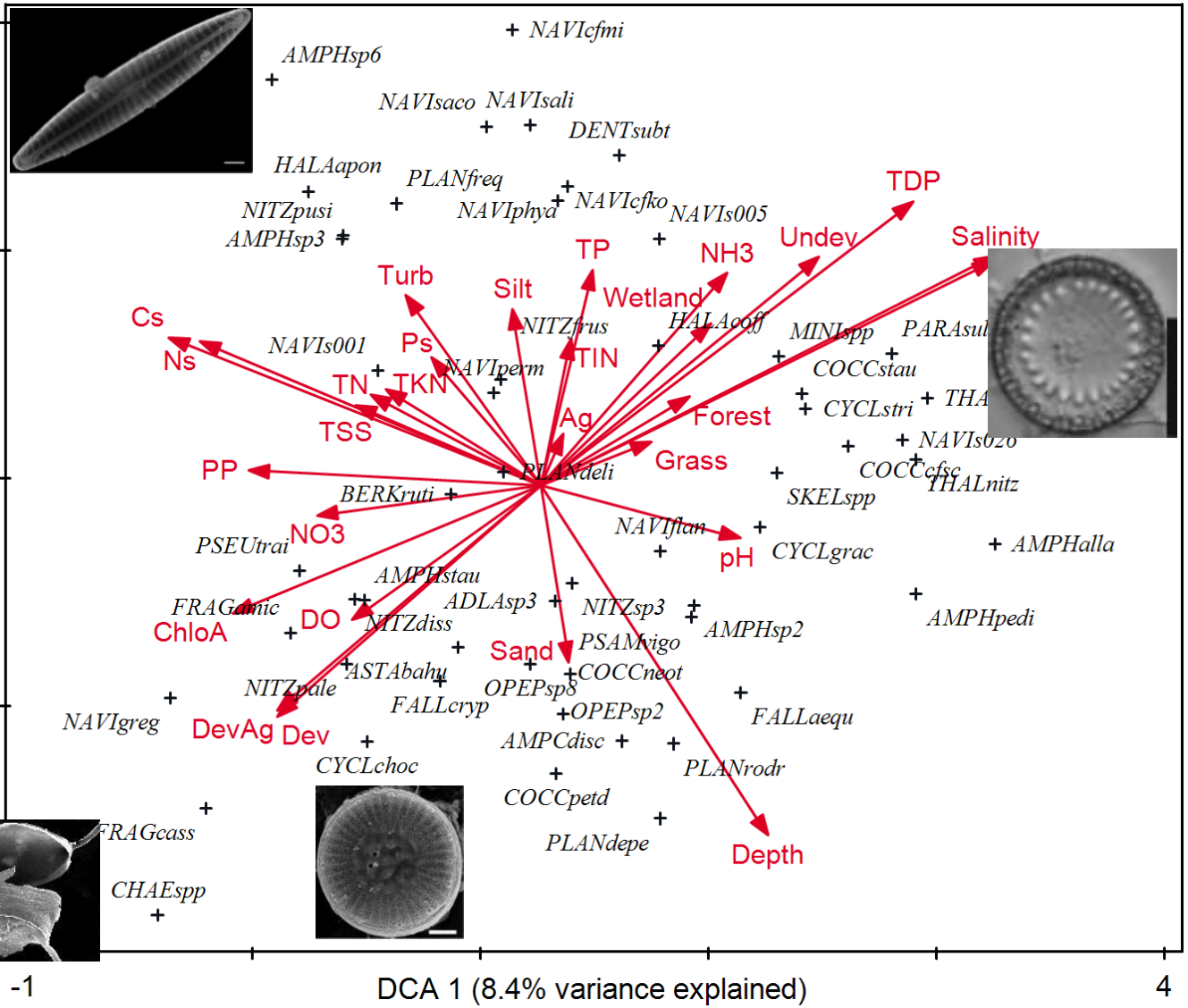
  Illustrate 499 species

- NE lakes Voucher flora (includes NJ lakes)-diatoms.org
- Pinelands ponds voucher flora ongoing



Example of calibration in Barnegat Bay





100 samples, 40 dominant species, 29 environmental variables

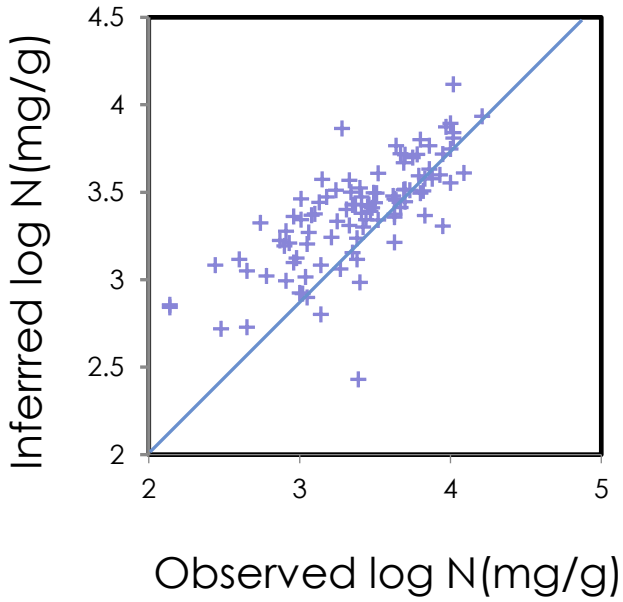
Strength of the relationships between diatom assemblage composition and environmental variables as measured by the significance of the first CCA axes

Environmental variable	F-ratio	P-value
Chlorophyll A, Log µg/L	**2.5**	**0.001**
Particulate Phosphorus, Log µg P/L	2.4	0.002
Total Dissolved Phosphorus, Log µg P/L	**3.5**	**0.001**
Total Phosphorus, Log µg P/L	**3.1**	**0.001**
Ammonia, Log µg N/L	2.0	0.006
Nitrate + Nitrite, Log µg N/L	2.5	0.004
Total Inorganic Nitrogen, µg N/L	2.3	0.002
Carbon sediment, Log µg/g	**4.2**	**0.001**
Nitrogen sediment, Log µg/g	**4.7**	**0.001**
Phosphorus sediment, Log µg/g	**3.3**	**0.001**
"Developed" land-use, sqrt %	**2.5**	**0.001**

* The effect of salinity is taken out

Weighted-averaging partial-least square inference model for sediment N, 2nd component:

$R^2 = 0.87$,
$R^2_{boot} = 0.55$
RMSEP = 0.30



Diatom-based environmental reconstructions

Present conditions

Present time metrics and indices
e.g., 1850 to present day

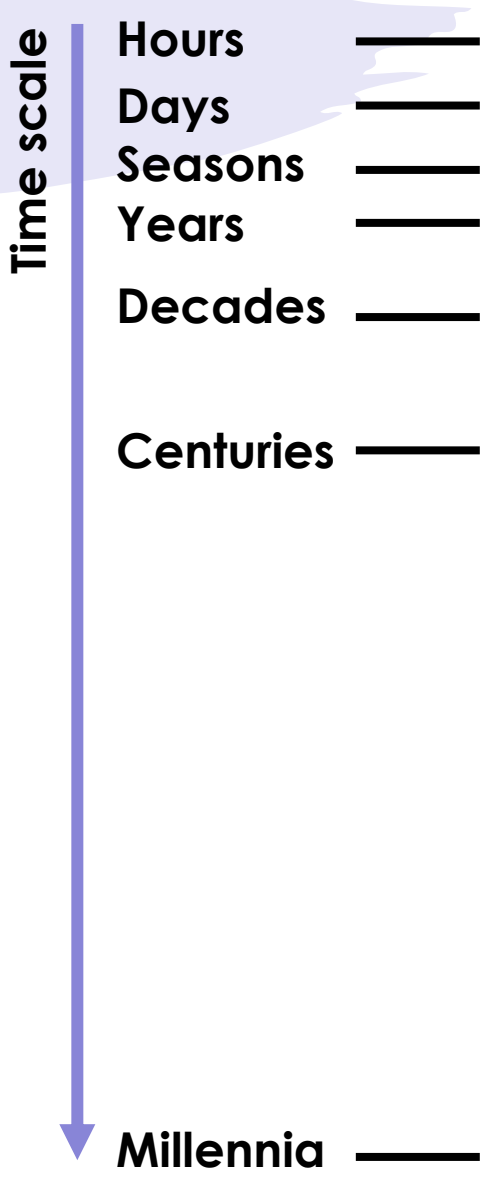
Early phase development/
Industrial revolution

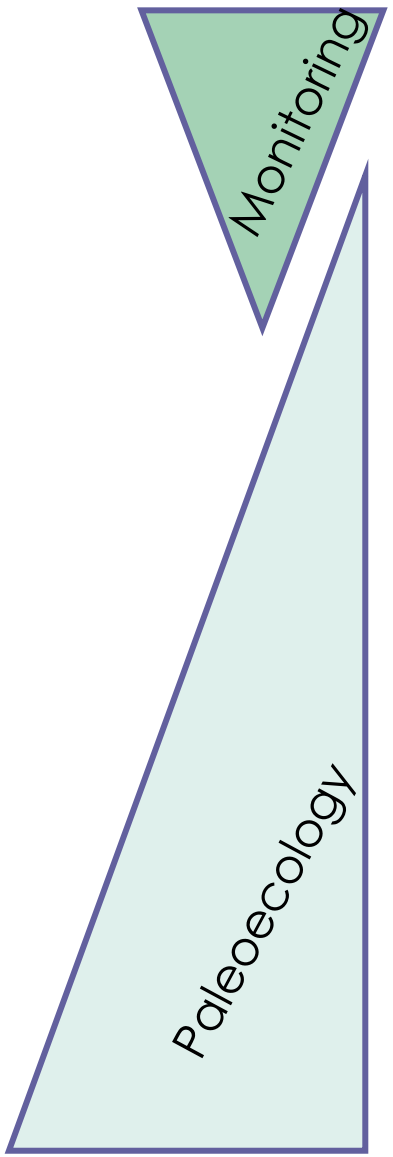
Pristine time metrics and indices
e.g., pre-1700s / pre-1850s

- **Once the calibration step is complete, the diatom-based transfer functions are ready to be used for reconstructing environmental parameters from sediment archives:**

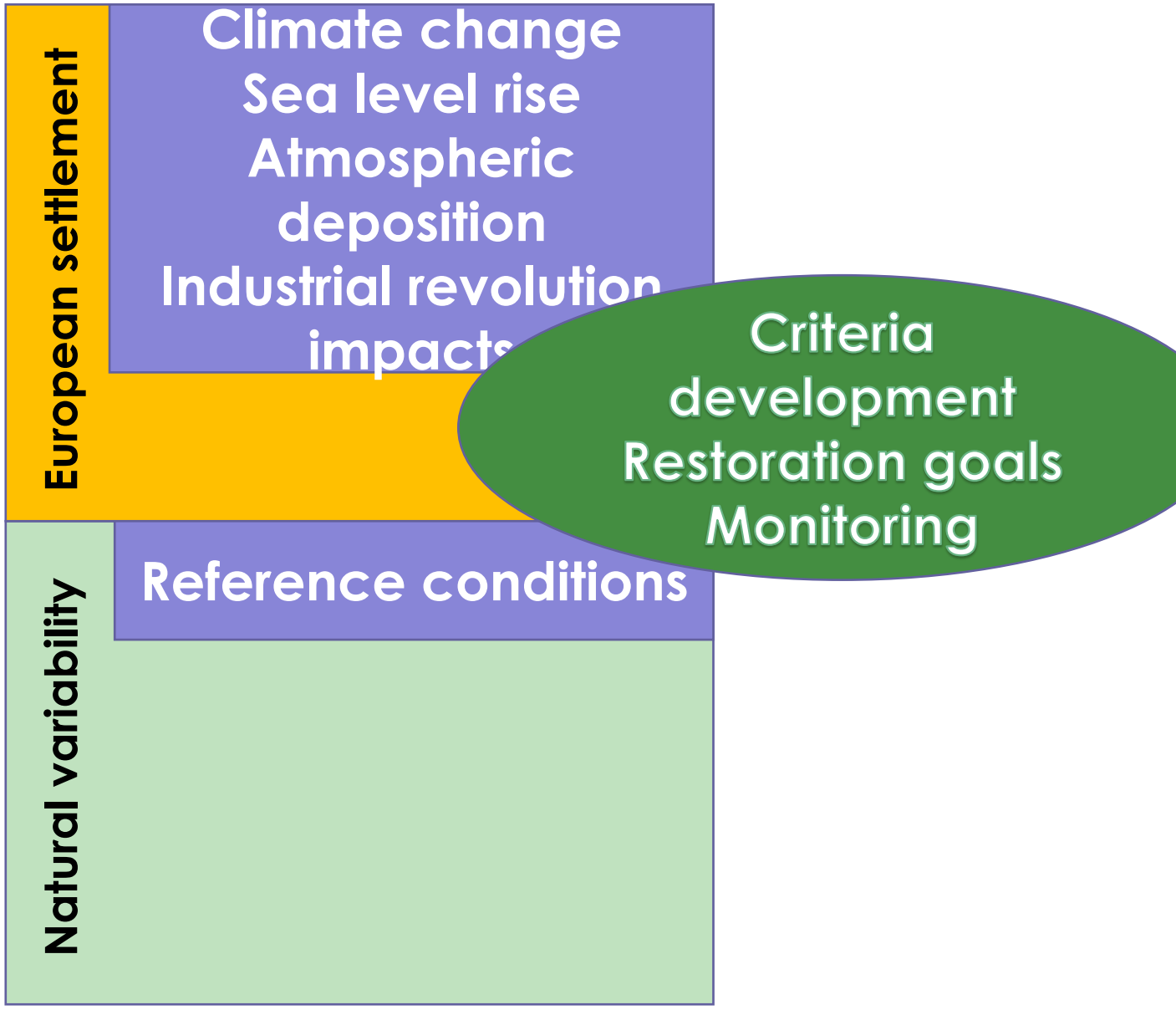
$$X=\hat{U}^{-1}Y$$

Sedimentary deposits information

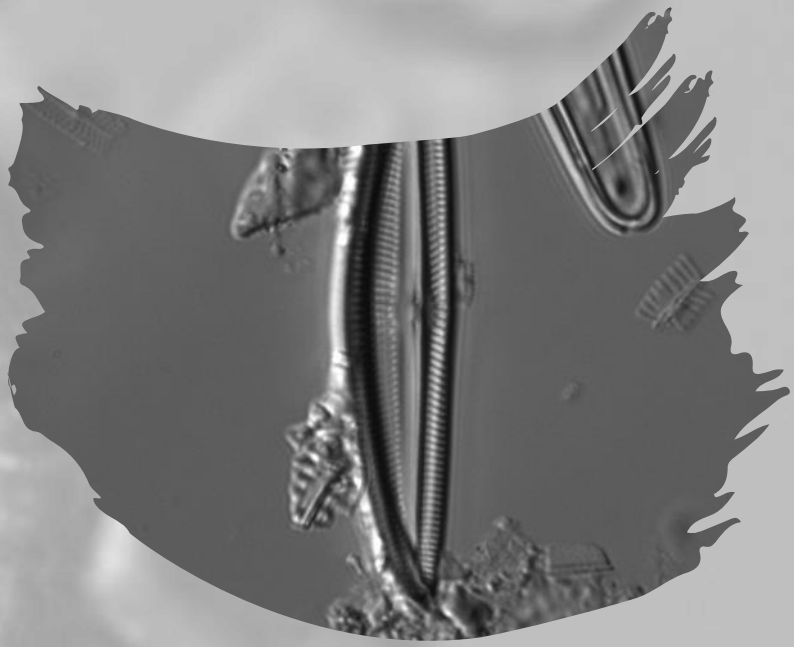


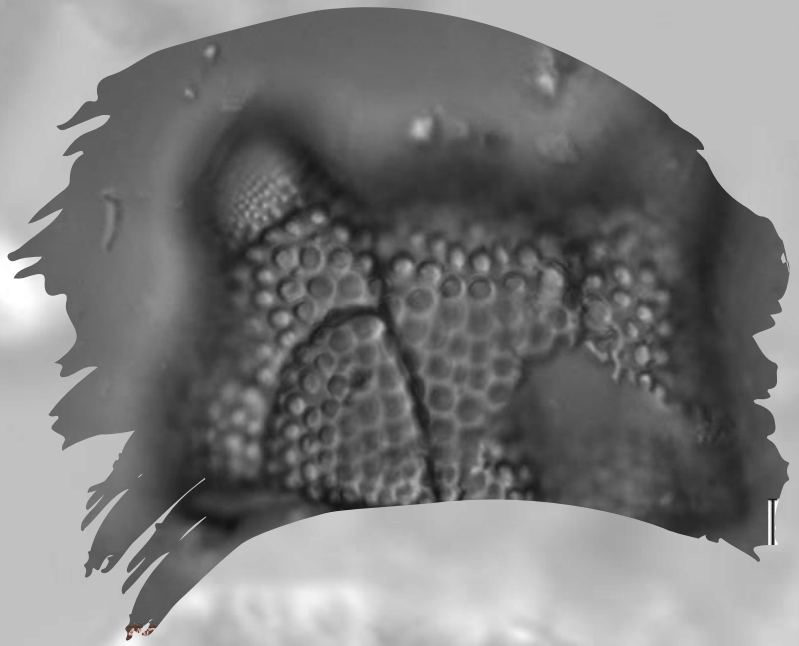


Modified from Smol 2008



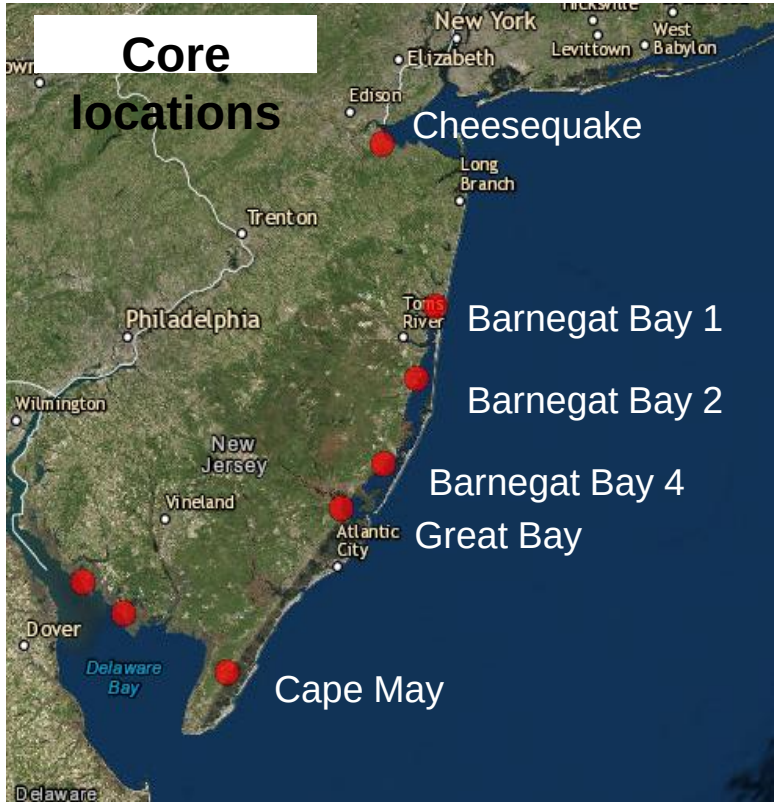
Diatom-based applications in New Jersey coastal wetlands

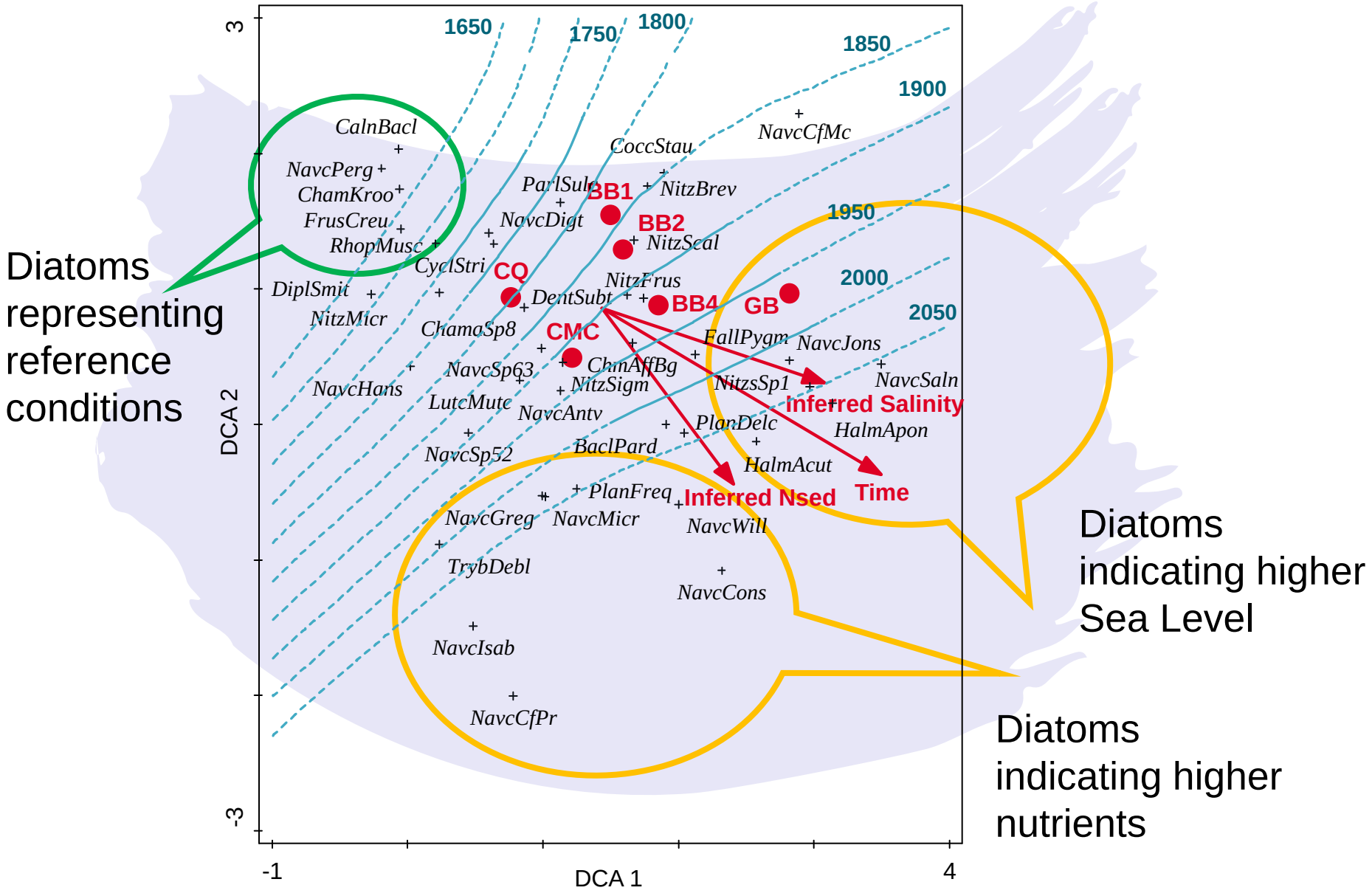




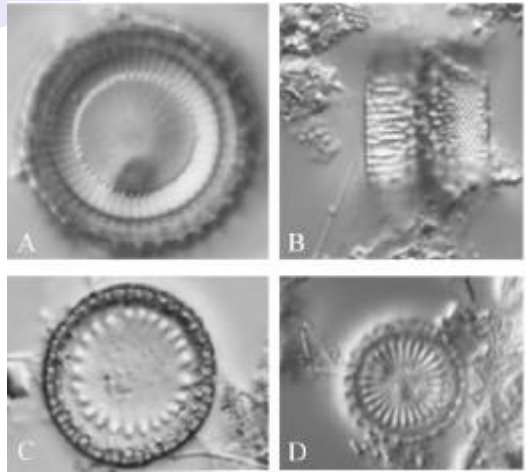
I. NJ wetlands reference conditions, European settlement effects and changes since the EPA's clean water act

- Six sediment cores were collected from N to south from coastal marshes
- The goal was to reconstruct reference conditions, the impact of European settlement, and relationships to current conditions
- Evaluate importance of change for management practices
- Two additional cores in DE estuary were collected to evaluate impact and recovery after strong erosion events
- New Jersey (USA) Wetlands Past, Present and Future: Using Sediment Archives to Inform and Guide Wetland Protection, Restoration and Resilience

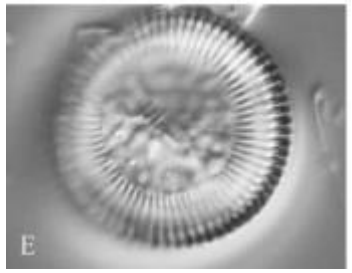



Diatoms representing reference conditions
1650
1750
1800
1850
1900
1950
2000
2050
CalnBacl
NavcPerg
ChamKroo
FrusCreu
RhopMusc
CyclStri
DiplSmit
NitzMicr
ChamaSp8
NavcHans
NavcSp63
LutcMute
NavcSp52
NavcGreg
TrybDebl
NavcIsab
NavcCfPr
ParlSulc
NavcDigt
CoccStau
NavcCfMc
BB1
BB2
NitzBrev
NitzScal
CQ
NitzFrus
DentSubt
BB4
GB
CMC
ChnAffBg
NitzSigm
NavcAntv
BaclPard
PlanFreq
NavcMicr
NavcWill
NavcCons
FallPygm
NavcJons
NitzsSp1
NavcSaln
HalmApon
PlanDelc
HalmAcut
Inferred Salinity
Inferred Nsed
Time
Diatoms indicating higher Sea Level
Diatoms indicating higher nutrients
DCA 2
DCA 1
3
-3
-1
4

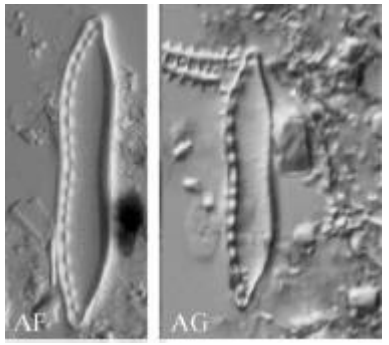
Reference diatoms



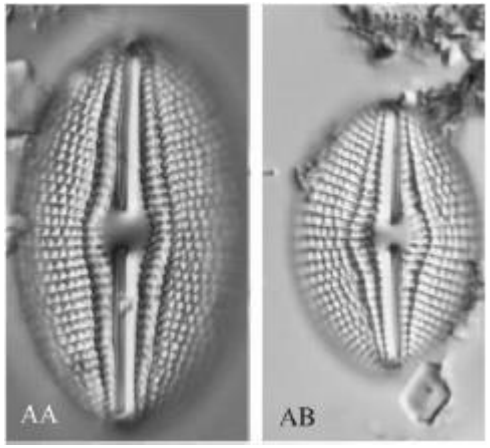
Paralia sulcata



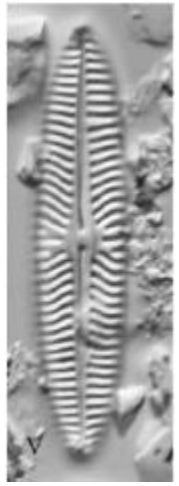
Cyclotella striata



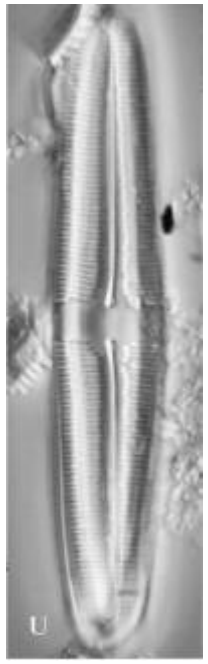
Nitzschia brevissima



Diploneis smithii

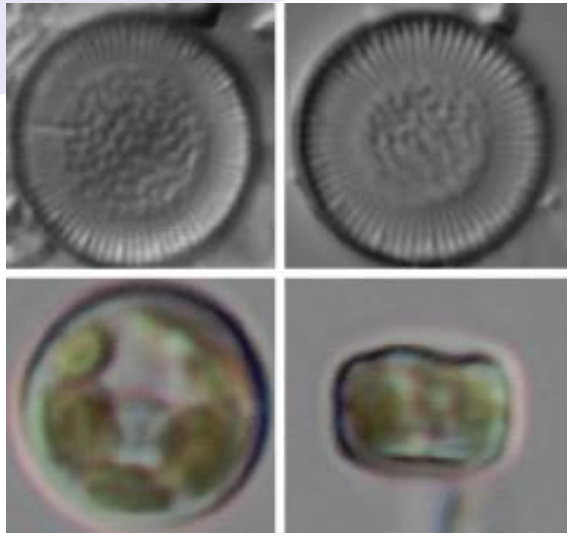


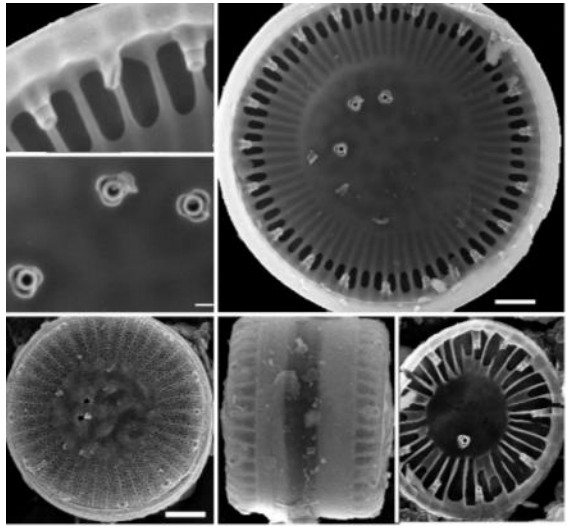
Navicula digitoradiata



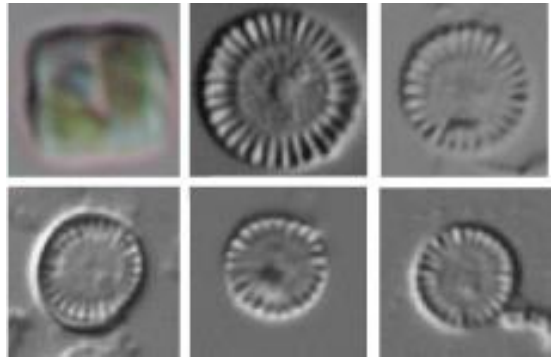
Caloneis bacillum

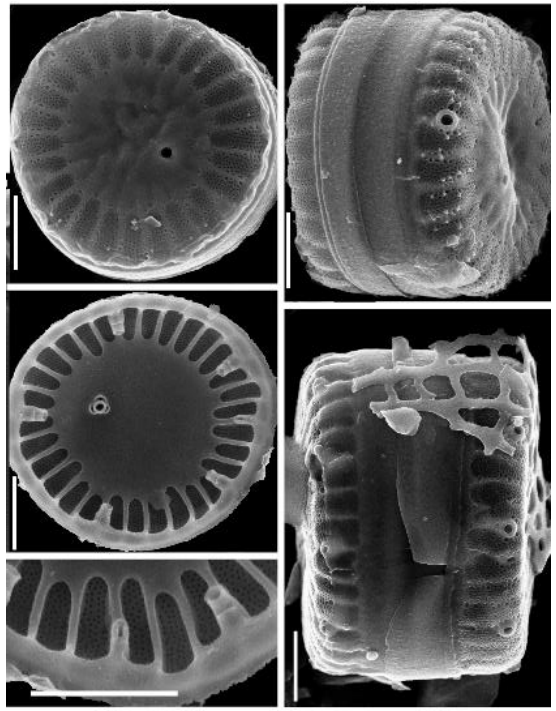
High nitrogen indicators



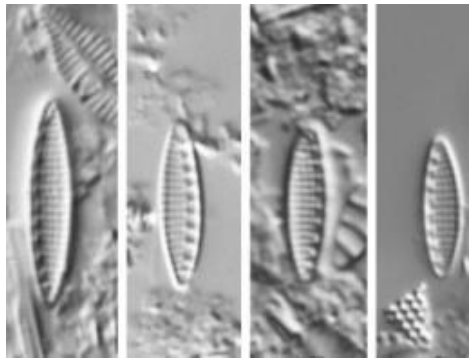


Cyclotella choctawatcheeana

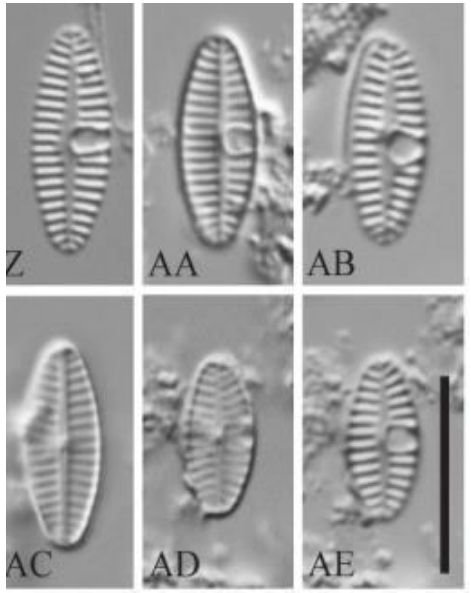




Cyclotella atomus var. *gracilis*



Nitzschia frustulum



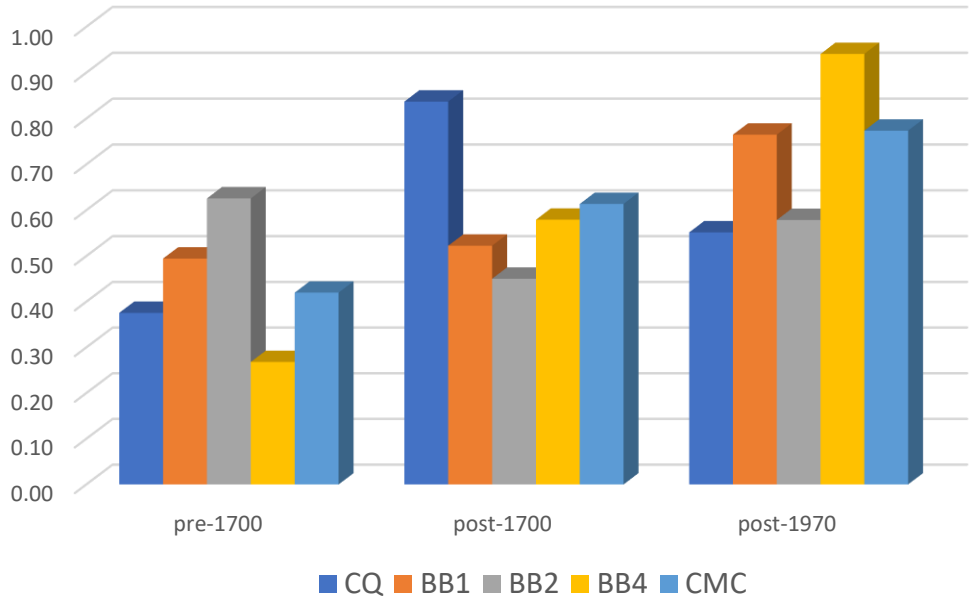
Planothidium frequentissimum

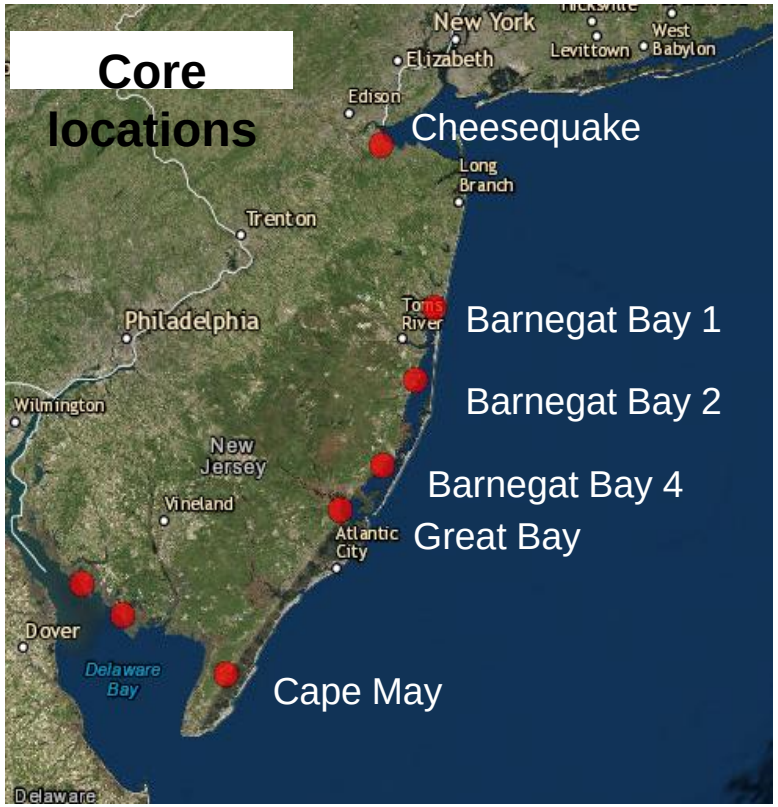
Ref species with monitoring potential

Indicator	Reference conditions			Present-day conditions		
Diatom species	HD	MD	LD	HD	MD	LD
Amphicocconeis disculoides	Y	Y	Y	N	N	N
Caloneis bacillum	Y	Y	Y	N	Y	Y
Cocconeis placentula var. lineata	Y	Y	Y	N	N	N
Cocconeis stauroneiformis	Y	Y	Y	N	Y	N
Cosmioneis pusilla	Y	Y	Y	Y	N	N
Cyclotella striata	Y	Y	Y	Y	Y	Y
Cymatosira belgica	Y	Y	Y	N	N	Y
Frustulia creuzburgensis	Y	Y	Y	N	Y	Y
Navicula digitoconvergens	Y	Y	Y	Y	Y	Y
Navicula peregrina	Y	Y	Y	N	Y	Y
Opephora sp. 2 COAST	Y	Y	Y	N	N	N
Paralia sulcata	Y	Y	Y	Y	Y	Y
Rhopalodia musculus	Y	Y	Y	Y	N	N
Thalassionema nitzschioides	Y	Y	Y	Y	N	Y
Thalassiora oestrupii	Y	Y	Y	Y	N	Y
Inferred Nitrogen Min-Max (%)	0.2-0.8	0.1-0.9	0.2-2.1*	0.4-0.8	0.6-1.2	0.2-0.6
Salinity Min-Max (psu)	16-30	12-29	12-29*	20-27	11-27	25-29

Condition assessment and restoration goals

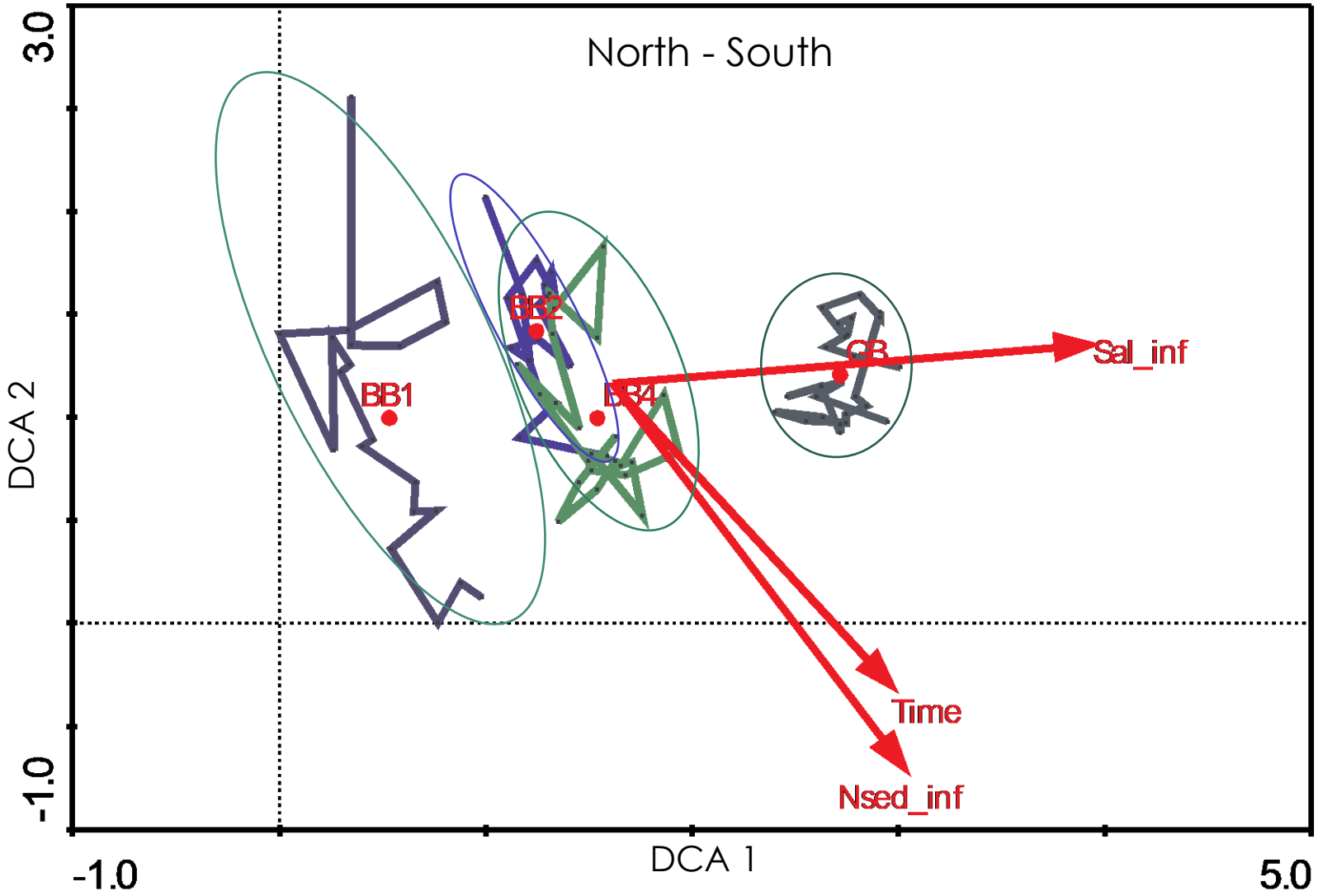
- What are reference nutrient concentrations? Impact of human activities?
- How did the EPA Clean water act impact wetland nutrient values?
- Nutrient pollution – which sites must be prioritized for restoration practices?





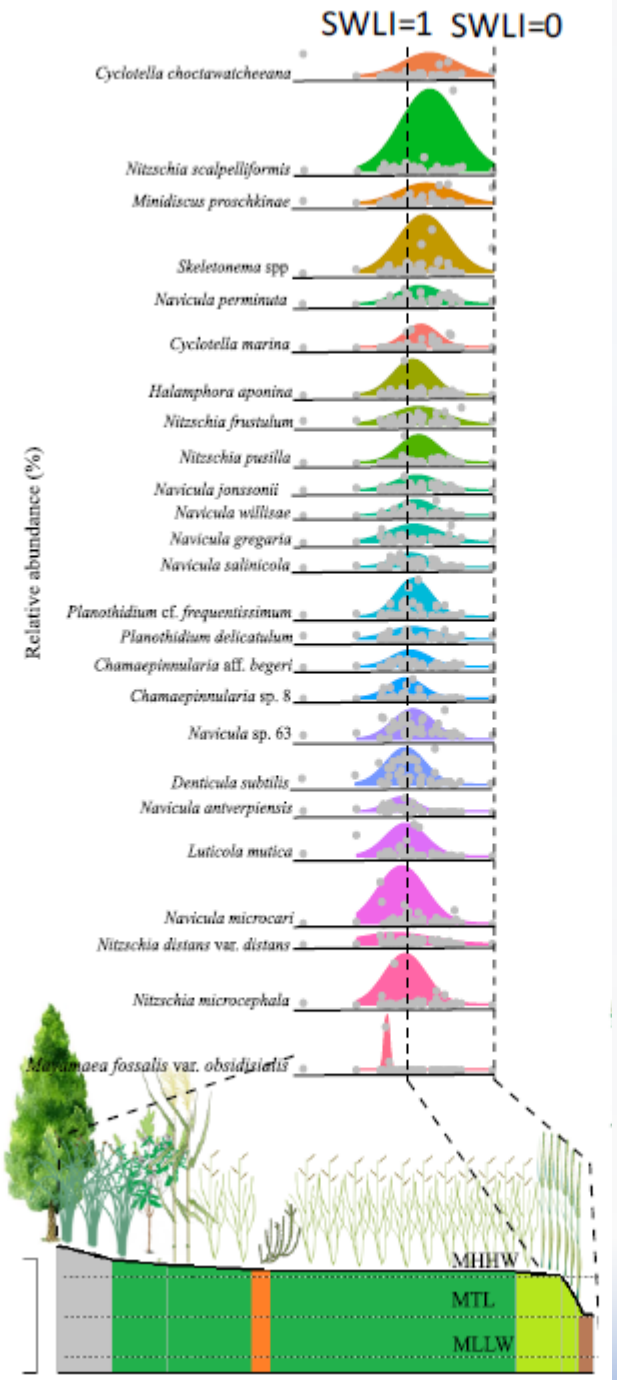
Setting monitoring and restoration goals

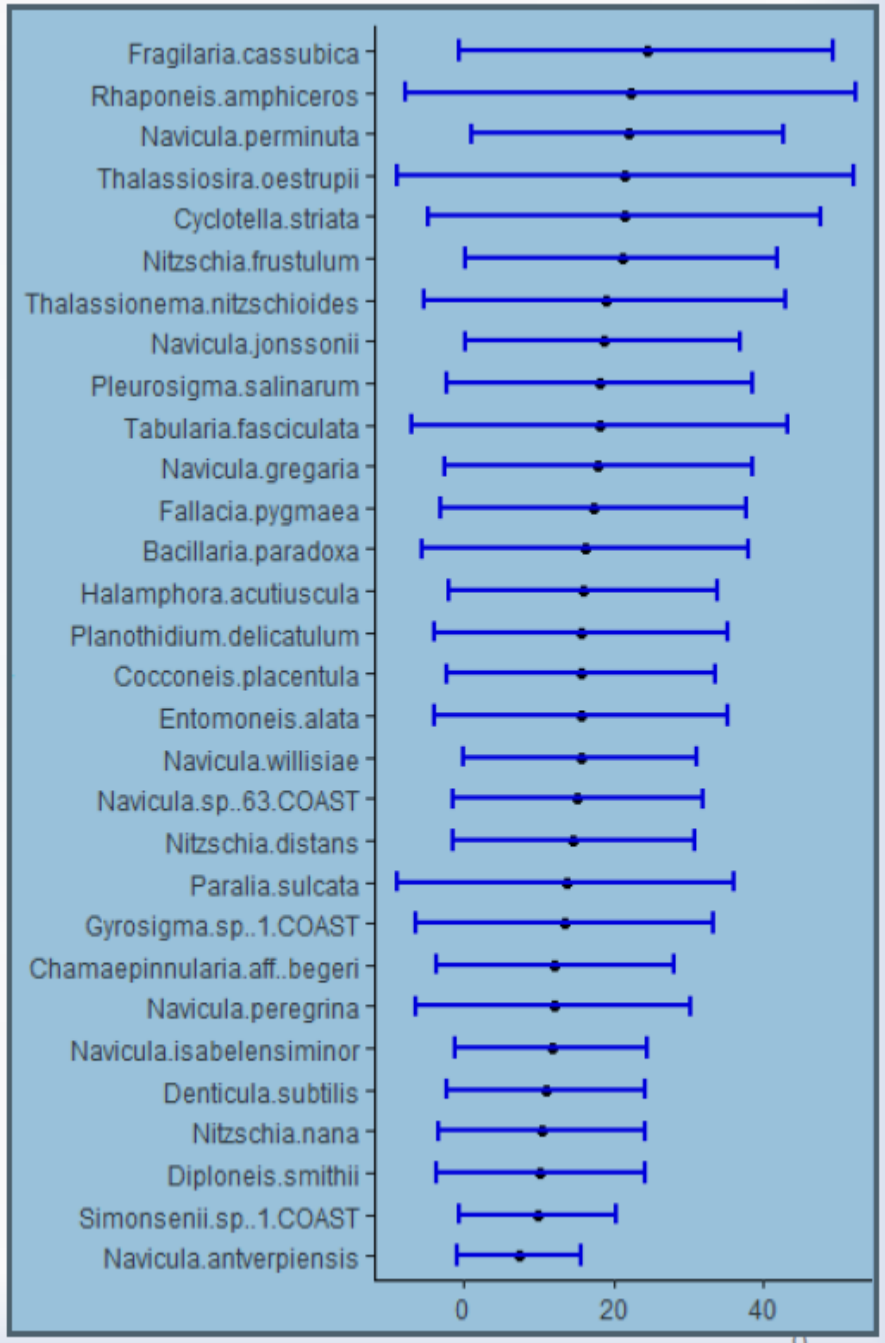
Increase in species associated with nutrient pollution in north; and sea level rise in south



2. Wetlands diatoms indicate tidal exposure / SLR impacts

- ~900 diatoms species, 1/3 new to science in NJ wetlands
- Diatom wetland Voucher flora – available on DSR website
- Calibration set 388 modern samples NJ-NY
- Transfer functions developed for salinity, TN and tidal exposure: TEI & SWLI
- Desianti et al. 2019 Estuaries and Coasts

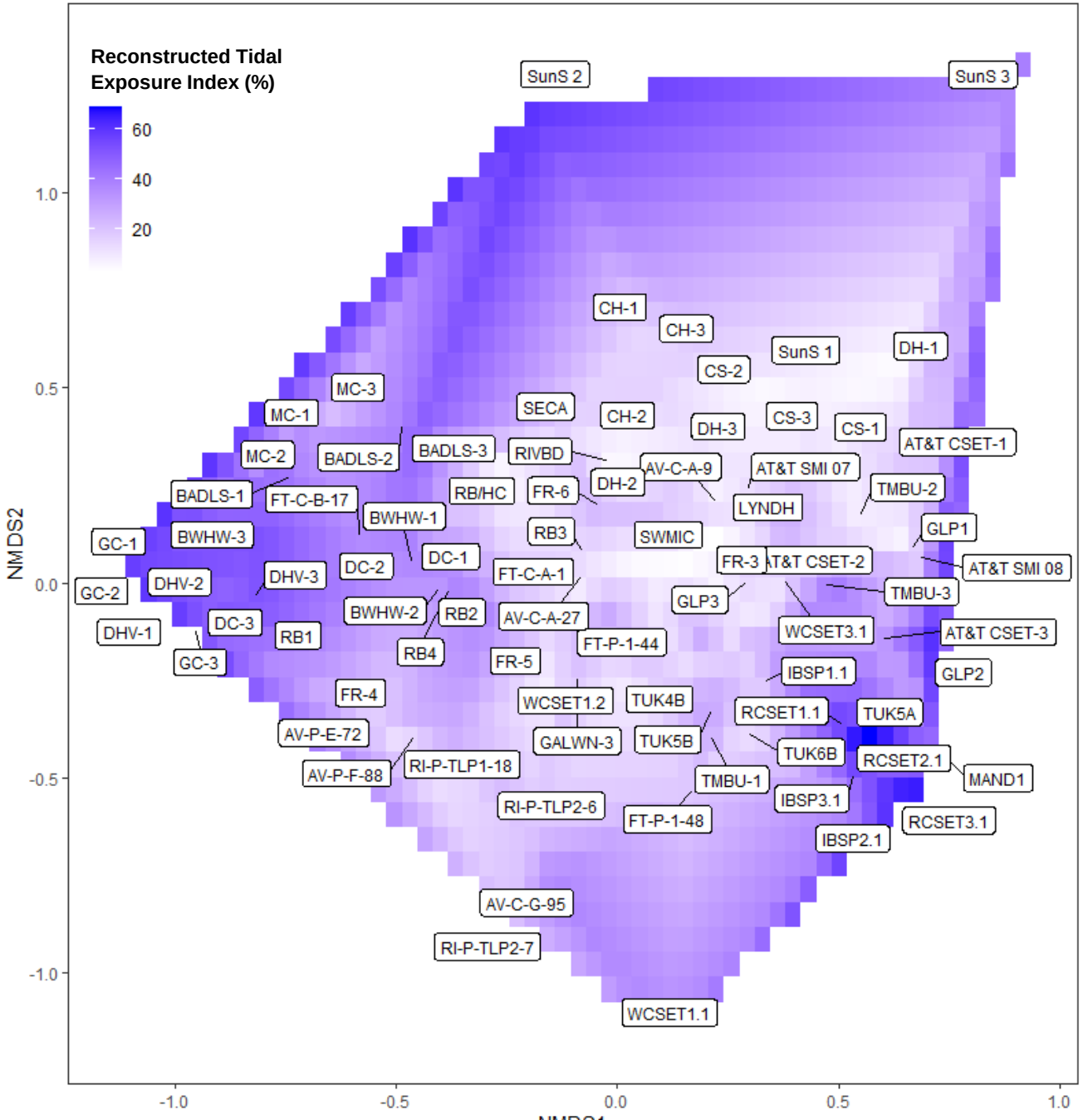




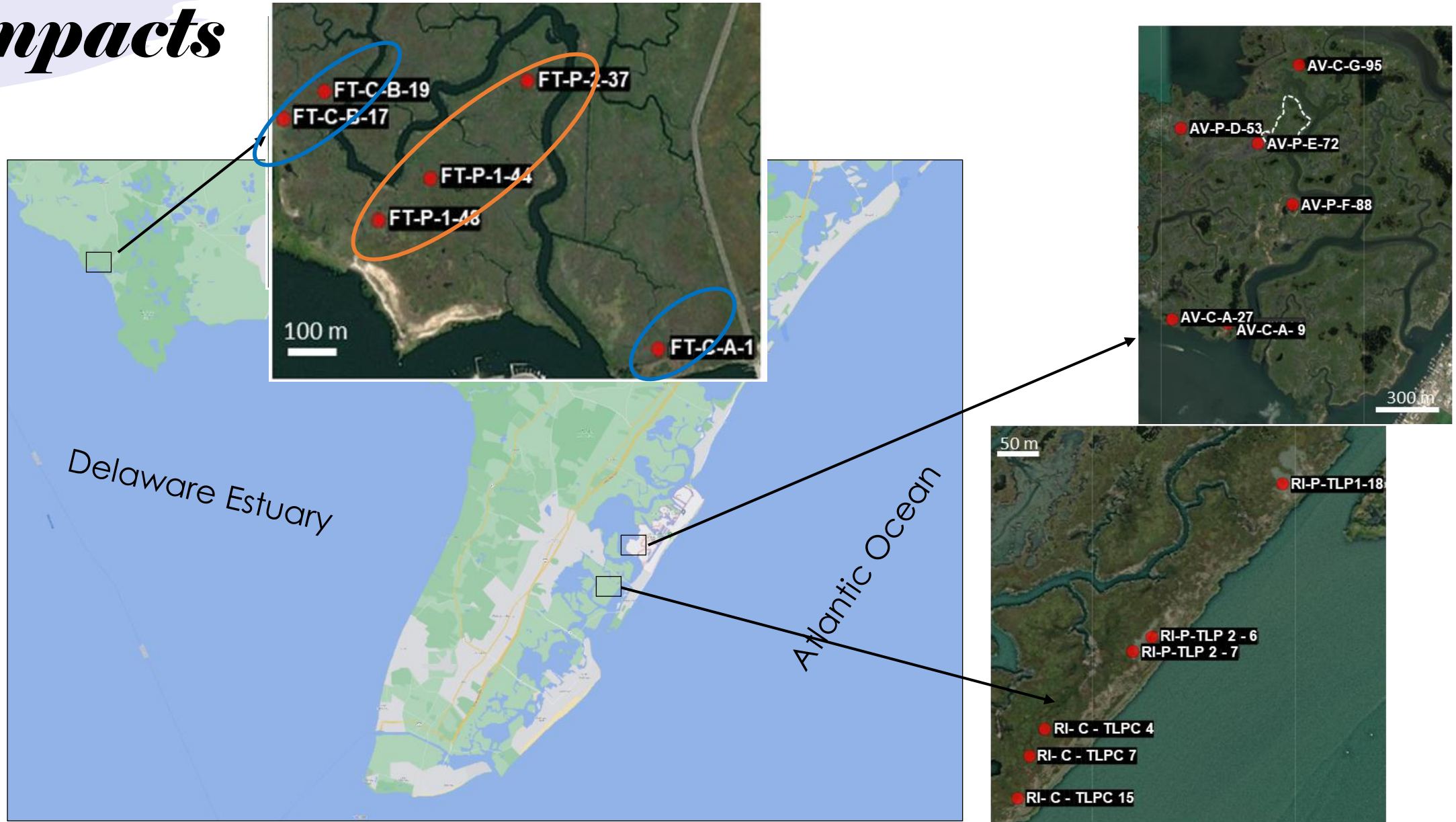
NMDS ordinations of 100 sites across New Jersey salt marshes.

Contour map of the diatom-based inferred values of the Tidal Exposure Index (TEI) is generated via interpolating inferred values of TEI.

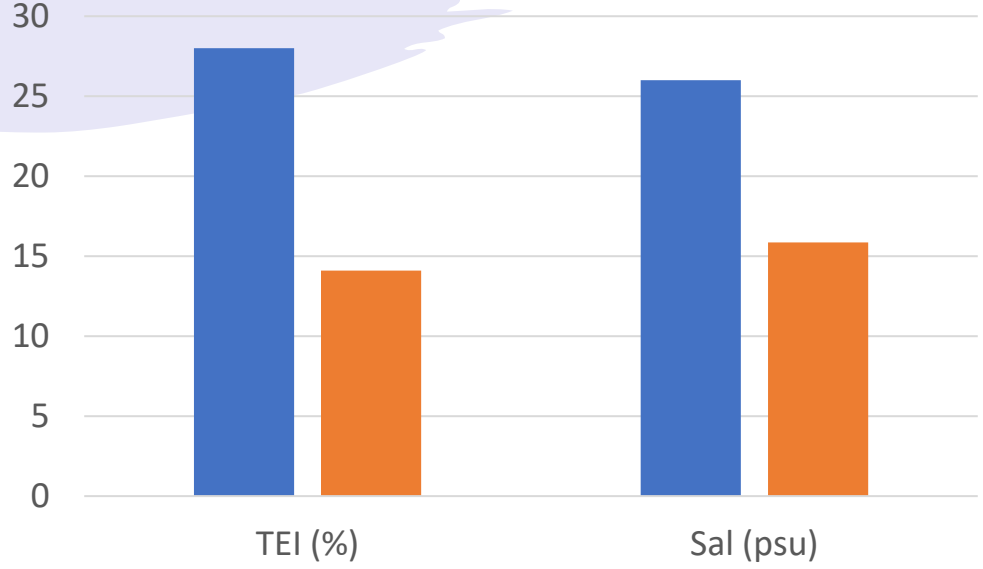
Allows identification of sites most exposed to tidal impacts: e.g., TUK5A, etc.

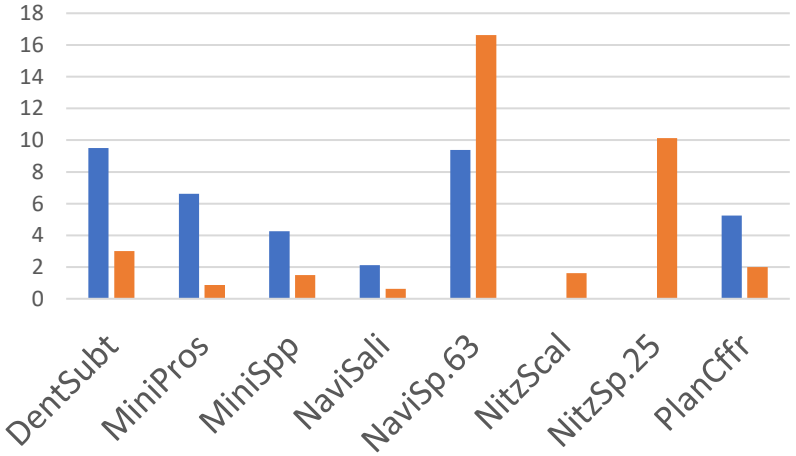


3. Assessment of Thin Layer Placement impacts



Fortescue comparison TLP and Control sites

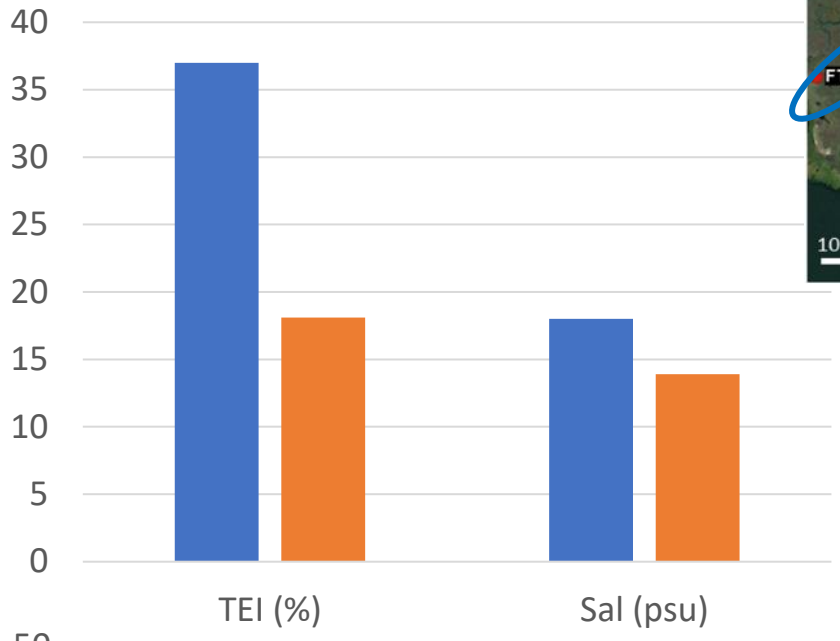


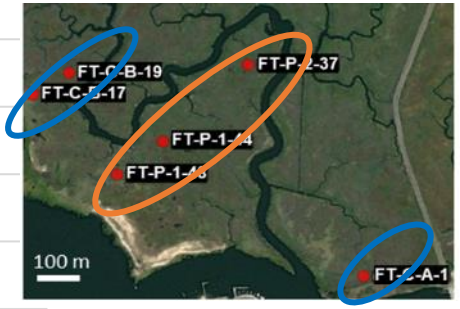


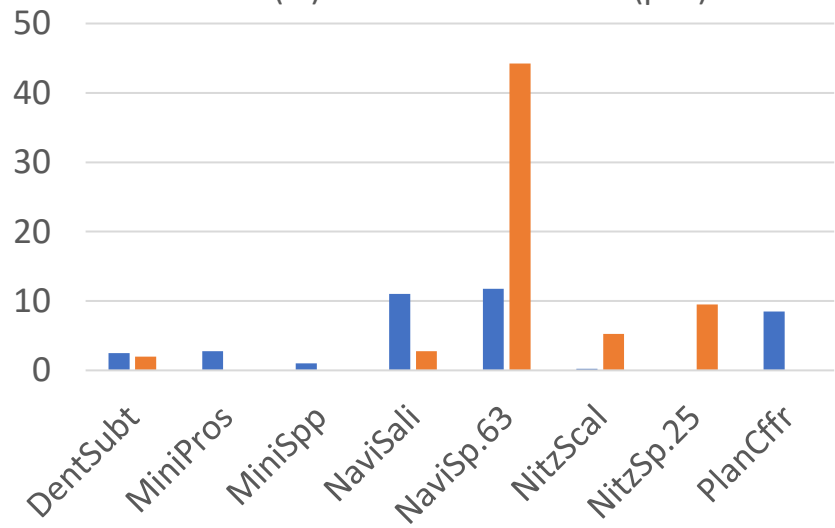
Low Marsh: FTP 1 44; FTP 2 37
FTC B 19; FTCB 17

CONTROL

TLP

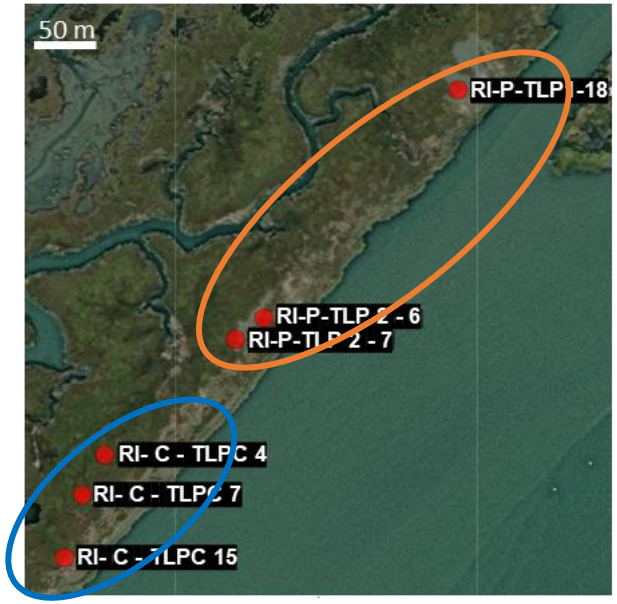




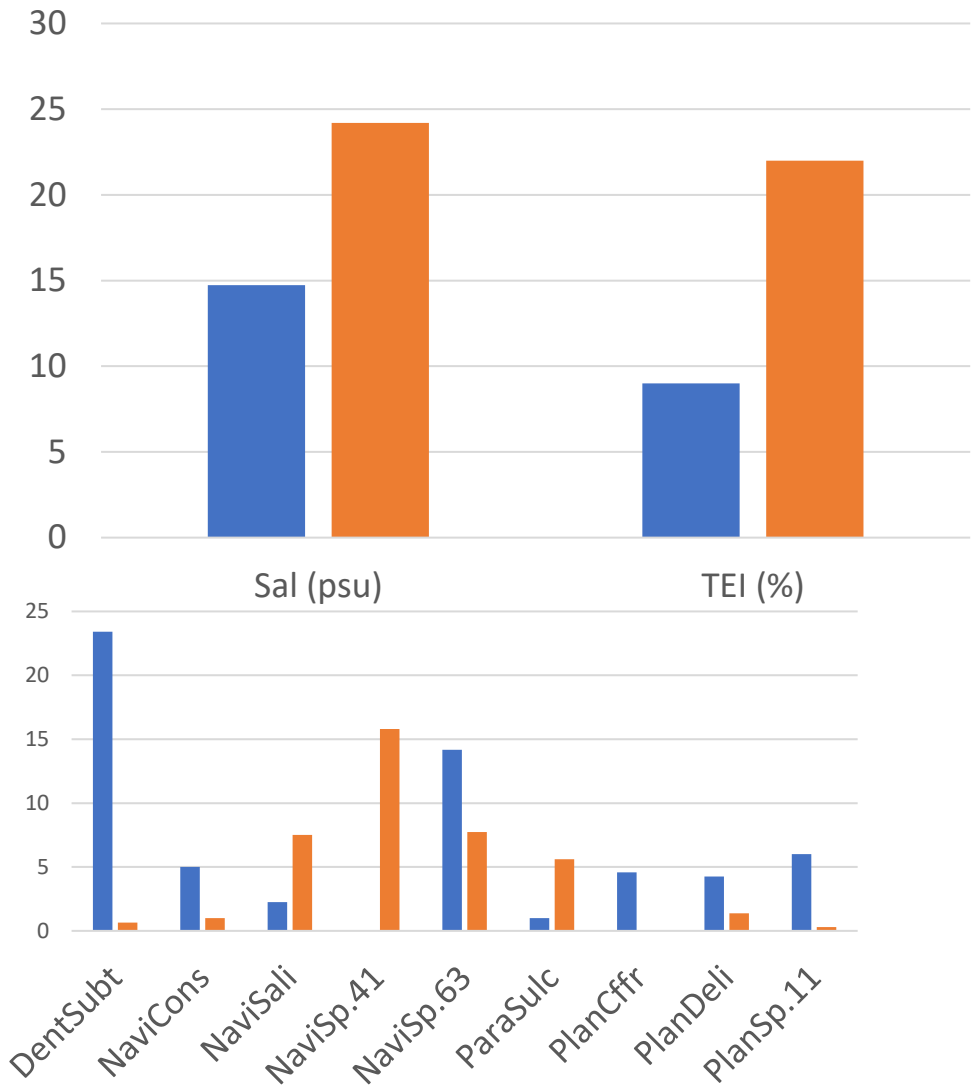


High Marsh: FTP 1 48
FTC A 1

Ring Island comparison TLP and Control sites



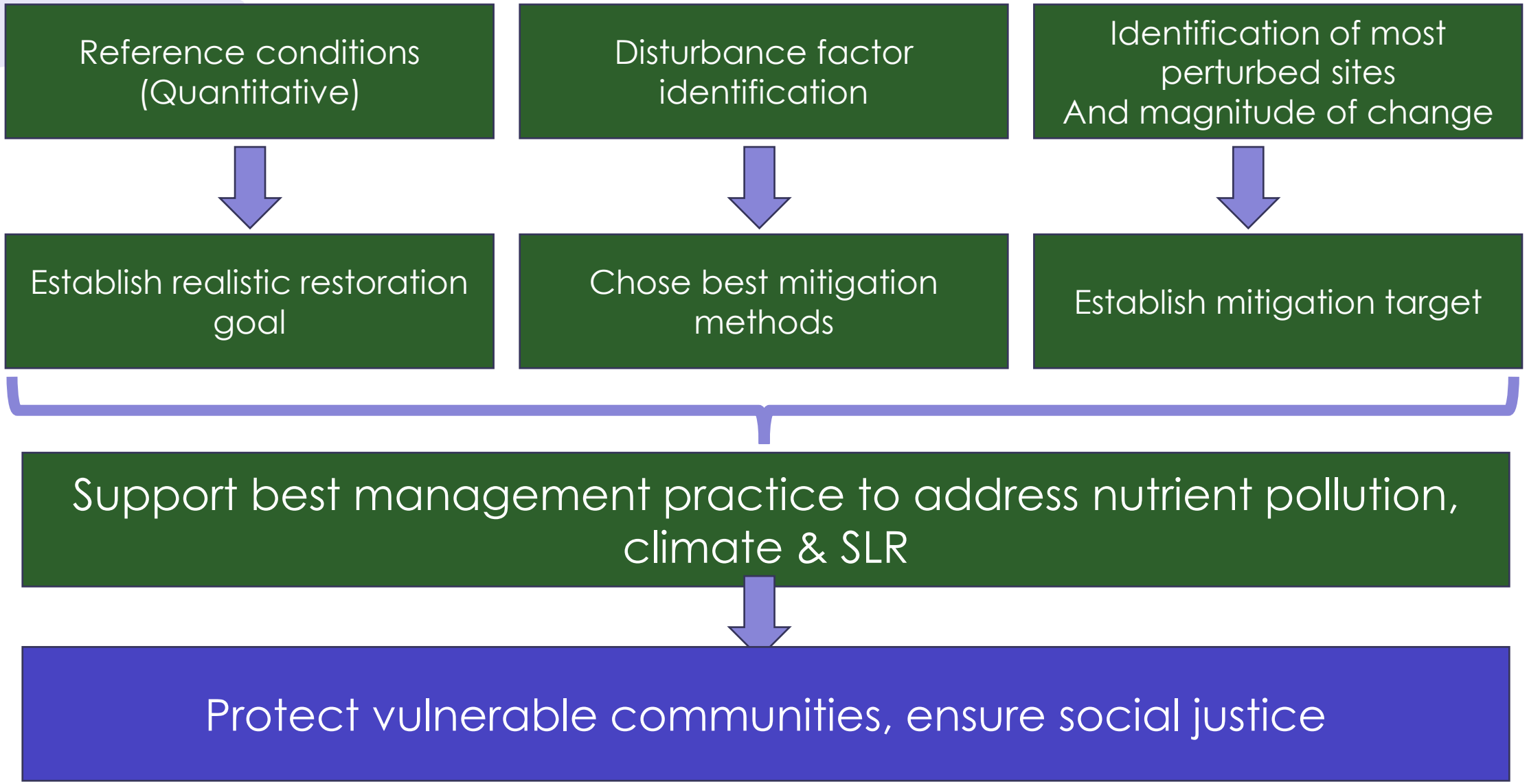
All low marsh sites



CONTROL

TLP

Diatoms management applications Summary



Other DSR projects involving wetland sediment cores/diatoms/other microorganisms

- Sea Level reconstruction over the last 1k at Dennis Creek – Dr. J Walker, Rowan U
- Diatoms and relationships to pore water chemistry – in report: Mapping and Assessing Tidal Marsh Condition Via Multispectral Imaging
- Harmful algal blooms in salt marsh ponds – ongoing, Drs Ling Ren/Pat Gillevet GMU. Manuscript submitted

Future diatoms applications: Develop diatom D.N.A procedures for assessment and biomonitoring

Thank you!