WILLARD SPUR SCIENCE PANEL MEETING
SEPTEMBER 22, 2011

NAME/AFFILIATION

Jim Hagy*	U.S. EPA, Office of Research & Development
Karin Kettinring*	Utah State University
John Luft*	Utah Division of Wildlife Resources
Theron Miller*	Farmington Bay/Jordan River Water Quality Council
Jeff Ostermiller*	Utah Division of Water Quality
David Tarboton*	Utah State University
Jeff DenBleyker	CH2M HILL
Jodi Gardberg	Utah Division of Water Quality
Chris Bittner	Utah Division of Water Quality
Cory Angeroth	USGS

*indicates Science Panel member

The following represents a summary of highlights in discussion. It is not intended to serve as detailed meeting minutes.

OBJECTIVES FOR MEETING

The primary objective of this meeting was to develop a list of research studies can be further developed into a research plan for this effort. Science Panel members were asked to come prepared with brief remarks to answer three questions that framed the agenda for the day's discussions:

1. How does your work as a scientist link to or help address the elements, linkages, and/or factors included in the draft conceptual models?
2. What key objectives do we need to achieve, i.e., questions do we need to answer, to address the program objective?
3. What studies do you recommend as the most critical to addressing the objectives of the program? How would you prioritize them?

PAST OR ONGOING WORK THAT COULD CONTRIBUTE TO THIS WORK

Each panel member was asked to briefly discuss past or ongoing work they had been involved with or thought may be applicable to this effort.

JEFF OSTERMILLER
Jeff prepared a handout that identified five areas that the Division of Water Quality is currently addressing that may be of value to this work (see pages 1-2 of Attachment 1 for additional detail):

1. Great Salt Lake wetlands assessments and mapping of invasive vegetation
2. Nutrient criteria development for State waters
3. Biological assessment methods
4. Ecological risk assessments for mercury and selenium
5. Water quality models

JOHN LUFT
John described bird surveys that the Division of Wildlife Resources (DWR) has completed for more than ten years across Great Salt Lake (GSL). These surveys encompass a wide range of lake levels and hydrologic conditions. Surveys primarily tracked bird species, populations, and looked at how the location of these populations across GSL varied year to year.

Ongoing bird surveys typically cover 25% of available GSL habitat and are completed 5 times per year. Bird surveys typically target spring migrations (April – June), fall migrations (July – September), and wintering bird populations (October – April). Nesting populations have not been a focus in recent years. The original 5-year intensive survey (1997 – 2001) included surveys 17 times per year. See http://wildlife.utah.gov/gsl/waterbirdsurvey/ for a summary of the 5-year survey. DWR currently completes 4 transects in an east to west direction in Willard Spur and will have completed 5 surveys in 2011. BioWest has also completed bird surveys in the Willard Spur area using helicopters and running on north/south transects. John has not seen their data but has provided DWR data to BioWest.

John said that Josh Vest has completed a bioenergetics model for waterfowl on GSL. Josh has a preliminary bioenergetics model for GSL shorebirds but there is a lack of data describing their feeding patterns and food items at GSL. The GSL Shorebird Conservation Plan is still in draft format but includes a description of the preliminary bioenergetics model for GSL shorebirds. Most of the diet data in this model is from the literature rather than from GSL-specific studies. Theron Miller noted that John Cavitt has been completing GSL diet studies for shorebirds and currently for waterfowl.

John noted that DWR has been funding work USGS is currently doing to model nutrients in the open waters of GSL.

Theron Miller

Theron has been involved in addressing the effects of nutrients on GSL wetlands since 2004. Theron summarized the work he has been involved using the nutrients conceptual model. The circles in Figure 1 represent targets of past research. Theron considered the red circles in Figure 1 as the most critical elements of the conceptual model. Theron said that he has not evaluated benthic algae and has no seen cyanobacteria blooms in the impounded wetlands. Reports summarizing the work Theron has been involved with are found at http://www.cdsewer.org/GSLRes/gslres.html .

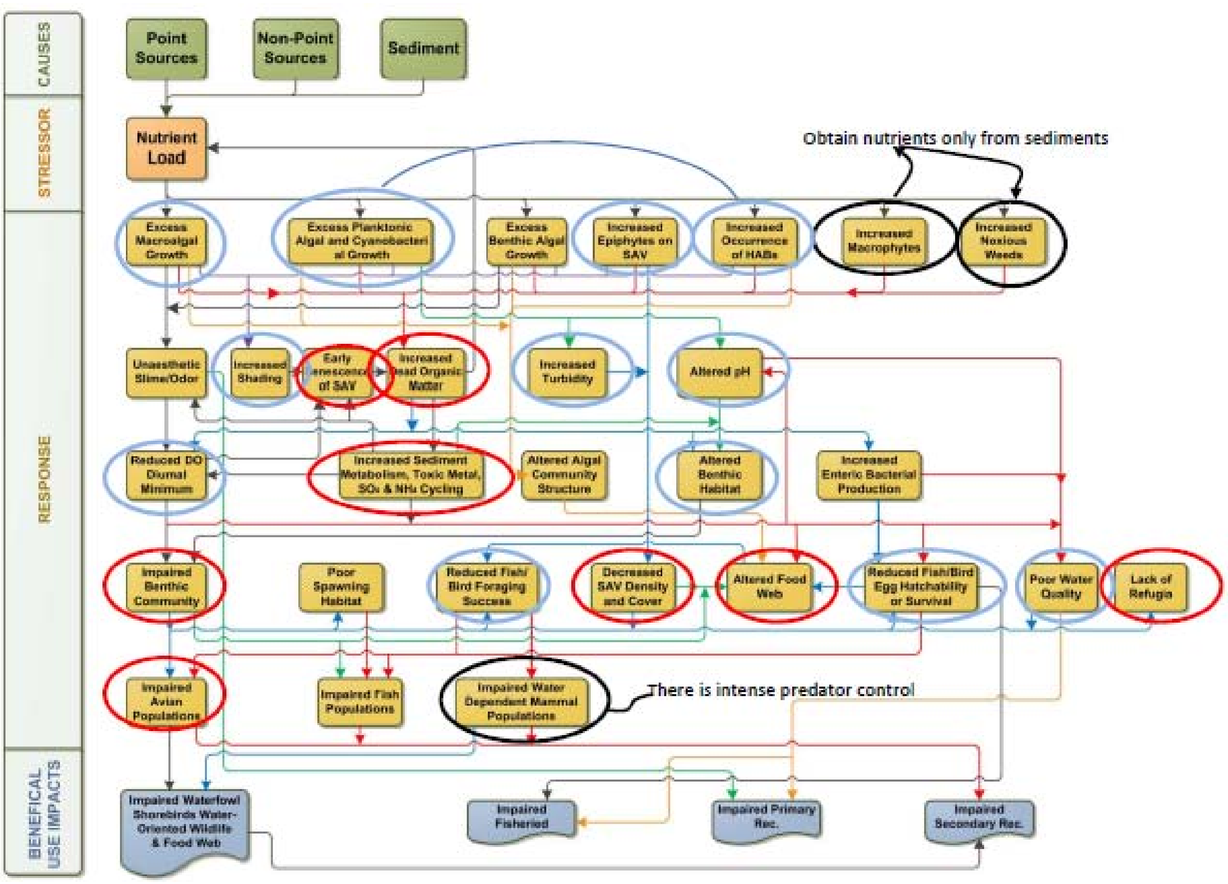


FIGURE 1
Summary of Theron Miller's Past Work; Circles Represent Areas of Past Work

There was some discussion about the significant changes in SAV and algae in Willard Spur even in the last month. SAV is beginning to senesce, phytoplankton is increasing, and something that looked like it might be cyanobacteria was observed. Understanding nutrient cycling between water, sediment, and SAV will be critical. Theron noted that we still do not know with certainty why SAV appears to senesce early.

David Tarboton

David has done extensive work looking at the sensitivity and variability of GSL water levels to runoff. He has evaluated inflow, evaporation, and the effect of potential withdrawals of water from GSL. He has completed other work linking hydrology with biological assessments in streams. He also has significant experience in the development of relational databases including the GSL Information System. http://www.greatsaltlakeinfo.org/

Karin Kettenring

Karin provided a handout summarizing her past work (see Attachment 2). She explained that there are various factors that affect the propagation of phragmites including moisture and perhaps nutrients. We do not have a good understanding of why phragmites are propagating so much on GSL. She is involved in a current effort to map vegetation, specifically phragmites, across the eastern third of GSL. Nutrients have been shown to increase seed production in phragmites but data describing other effects on phragmites are not as clear. Some pointed experiments may help determine the role of nutrients in phragmites propagation.

Karin also noted that Dr. Rosenberg at USU has been working on a system model for the Bear River Migratory Refuge that looks at water depth, duration and vegetation response. This may be of use for this project.

Jim Hagy

Jim summarized his previous work and other work that he thought was relevant to this effort (see Attachment 3). He provided a brief summary of other efforts in east coast estuaries to define nutrient budgets, the importance of identifying nutrient sources and loads, internal cycling of nutrients, identifying critical hydrologic regimes, the reconstruction of food webs, the importance of defining how nutrients impact the food chain, and flux of nutrients from sediments to the water column. Many, if not all, of these topics are of significant importance in Willard Spur. Jim has also had significant experience in the process of developing numeric criteria to protect water resources.

Key Objectives

The Science Panel was asked to identify key questions that would help frame the research required to address the program objective.

Jeff Ostermiller suggested that the two overarching questions that the study needs to address are (see his handout):

1. What are the potential impacts of the Perry Willard Regional Wastewater Treatment Plant on Willard Spur?
2. What will be required to provide long term protection of Willard Spur?

Jim Hagy provided a handout identifying three key research areas (see Attachment 4):

1. Define a nutrient and water budget for Willard Spur
2. Define the food web
3. Define eutrophication responses within Willard Spur

The Science Panel agreed that the research should be organized within the three areas identified by Jim Hagy to answer the two questions identified by Jeff Ostermiller.

The below provides a brief summary of additional topics discussed by the Science Panel during this session:

- Need to look at how Willard Spur varies by season. Perhaps look at spring (before vegetation begins), summer (when the area seems to be dominated by macrophytes), and fall (after vegetation senesces).
- Will need to determine how the hydrology affects water quality conditions amidst seasonal changes.
- Need to look at nutrient cycling and budget
- Should we spatially segregate the system? How?
- How do dry periods affect the sediments of Willard Spur?

- Karin noted that vegetation of GSL was first mapped in 1992. A second study was completed in 2004. Theron noted that additional mapping is available from 2005 (6?). Ducks Unlimited mapped vegetation in 2006 using available aerial photography.
- Theron noted the critical nature of understanding the sediment/water interface and sediments role in storing and providing nutrients to Willard Spur. See Figure 2.

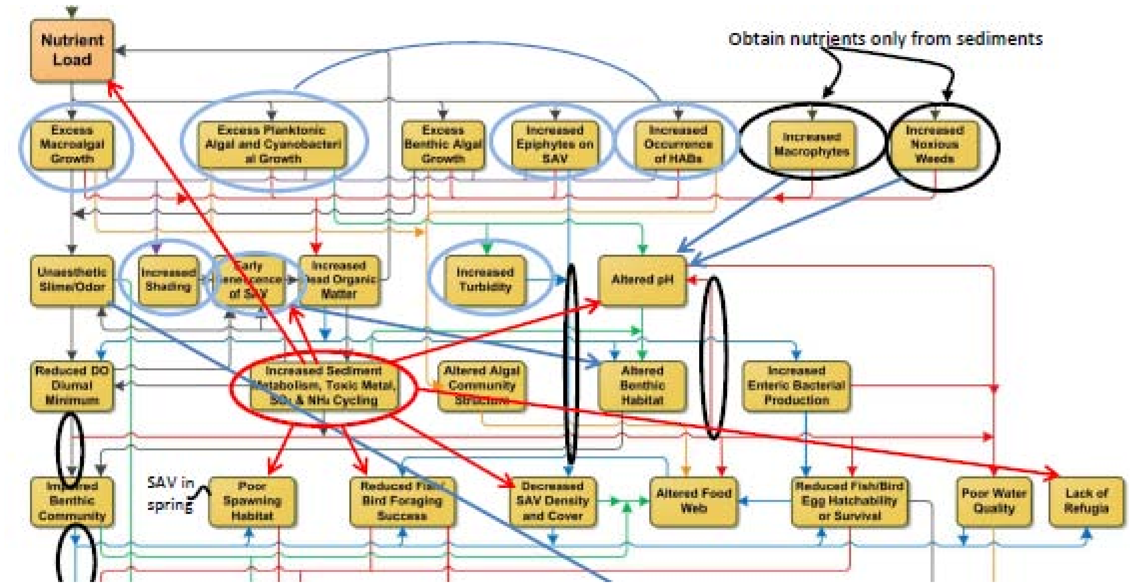


FIGURE 2
Link between sediments and other elements of nutrient conceptual model

- Jim noted that we have very little existing data. It may be too difficult, if not impossible, to develop dynamic simulations of Willard Spur that are meaningful. May have to emphasize the nutrient budget, how that might change, and then look at how Willard Spur is and has cycled nutrients. The Panel agreed.

Recommended Studies

The Science Panel was asked to identify studies they thought were critical to address the project objectives. Studies were identified for each of the three categories discussed previously.

Food Web

The Science Panel agreed that it will be important to determine if there is a link between the effects of nutrients upon the food web in Willard Spur. Thus, studies to define this food web, the carrying capacity of Willard Spur for various birds, and then determine if there is a link to nutrients will be critical. The following studies were identified and discussed:

1. Continue bird surveys to define species and numbers
2. Identify what shorebirds are eating and where, spring and fall
3. Identify what waterfowl are eating and where, spring and fall
4. Identify what the piscivorous birds are eating and where, spring and fall
5. Build upon Josh Vest's energetic model for GSL shorebirds, need diet and energetic data, goal is to estimate carrying capacity of Willard Spur for shorebirds under various scenarios
6. John Cavitt investigating energetics for waterfowl, feeding habits, dietary preferences, energetics for those food items, need to update and build upon Josh Vest's energetic model for GSL waterfowl
7. Identify species, numbers, habitats for macroinvertebrates to link into energetic model, seasonal changes
8. Identify foraging habits for shorebirds to link birds to habitat and vegetation
9. Identify plant cover for fall migrating waterfowl, location, production of tubers/drupelets
10. Characterize species, numbers, and habitat for fish (shad, carp) A challenge will be to capture fish in shallow water that has significant SAV coverage. See Figure 3 for a suggested method from Jim Hagy. The ring is dropped

through the water column into the sediment. The contents within the ring, including fish, can then be enumerated.

11. Develop a model to pull it together
12. How do we evaluate energetic for food items? Energy vs carbon vs nutrients? It sounded like most work to date has been done in terms of energy.
13. What birds nest in Willard Spur, in what numbers/location? What habitat do they prefer? USFWS is doing some work in 2012 that may look into this.
14. What are drivers for vegetation cover?
    a. Mesochosm manipulating environmental factors, nutrients, growth rate, spread rate, seed production
    b. Historical changes in vegetation vs environmental data (sediment cores, water level, hydrology)

FIGURE 3
Drop-ring used to sample fish in shallow estuaries, photo courtesy Jim Hagy

Nutrient and Water Budget

The Science Panel agreed that understanding the sources and loading of nutrients will be important to understand the influence of the discharge from the Perry Willard Regional Wastewater Treatment Plant as well as how future loadings may affect Willard Spur. Understanding the water balance is central to the nutrient budget.

1. Maintain water monitoring, outflow, inflow, weather
    a. Evaluate current inflow/weather monitoring program, add outflow monitoring (DWQ is making attempts at measuring outflow, could possibly deploy continuous flow velocity measurement)
    b. Look at measuring water temperature to help calculate evaporation
    c. Explore a measurement of residence time through the use of a tracer for various flow regimes, DWQ and USGS to look into this again
    d. Investigate accuracy of bathymetry, is current mapping adequate or does it need to be supplemented. Then key is to be able to link water depth to habitat.
2. Autosampler at key inflow locations to look at daily/weekly variation, monthly grab samples may not be adequate
3. Investigate atmospheric deposition, there is a site in Logan that has been measuring nutrient deposition http://nadp.sws.uiuc.edu/sites/siteinfo.asp?net=NTN&id=UT01
4. Look at nutrient cycling - experimental design to identify how nutrients are cycled as macrophytes change, look at how water column, sediment, macroinvertebrates change. This is probably the most complex, but also critical, element in the research design.
5. Identify nutrient content of vegetation
6. Look at vertical profile of sediment, whole sediment chemistry and pore water chemistry, link to tuber density and drupelets

7. Sediment flux
8. Sediment profiles/deposition rates
9. Outflow – grab samples of water, enclosures to capture debris “flowing” out
10. What is the nutrient load from birds? Nutrient export via fish – birds
11. Measure nutrient content of macroinvertebrates

Eutrophication Responses

The response of the system to nutrients is a key linkage between loading and the food web. There is overlap between objectives for the nutrient budget studies (primarily #4) and understanding eutrophication responses but there are some additional studies that should be completed:

1. Measure biomass of macroalgae
2. Macroalgae “common garden” experiment
3. Isotopic analysis, begin by looking to see if there is a difference in signature from sources, then expand if promising, goal is to see if there is a link between point sources and nutrients in Willard Spur
4. Phytoplankton composition, link to nutrients and/or senescence of SAV?
5. Look at potential release of toxics in sediment
6. Satellite imagery – phytoplankton/macroalgae? Can we use available historic imagery to understand how Willard Spur has changed over time? Is water too shallow/clear?
7. Aerial imagery, is this a cost-effective method for quantifying macroalgae in Willard Spur?

Conclusions

The Science Panel agreed that there is a significant body of research that could be and should be completed to understand the influence of nutrients on this system. Research will need to maintain focus upon understanding and answering the two top questions:

1. What are the potential impacts of the Perry Willard Regional Wastewater Treatment Plant on Willard Spur?
2. What will be required to provide long term protection of Willard Spur?

The Science Panel agreed that Jeff DenBleyker will summarize the list of projects identified at this meeting, draft an objective for each project, and circulate this list to the Science Panel for review. The Science Panel will review and discuss comments in a conference call from 10:00am – 12:00pm MDT on Monday, October 3. DWQ will then work to incorporate this into a research plan that will be discussed in a conference call from 3:00 – 5:00pm MDT on Thursday, October 20. DWQ will then finalize the research plan to submit to the Steering Committee for review. The Science Panel will meet at DWQ, via conf call for those not local, on November 3 and attend the Steering Committee meeting to address any questions. Below is a summary of upcoming meetings:

Upcoming Meetings

Science Panel Conference Call	10:00am – 12:00pm	Monday, October 3, 2011
Science Panel Conference Call	3:00 – 5:00pm	Thursday, October 20, 2011
Science Panel Meeting	1:00 – 3:00pm	Thursday, November 3, 2011
Steering Committee Meeting	3:00 – 5:00pm	Thursday, November 3, 2011

Attachment 1

WQM: Research Activities

Wetlands

http://www.deq.utah.gov/Issues/gslwetlands/index.htm

- Refining assessment tools for impounded wetlands
- Developing assessment methods for “fringe wetlands” (2011 & 2012)
- ***Collecting numerous water quality indicators from 50 randomly selected wetlands in 2012; indicators include: macroinvertebrates, zooplankton, algae/diatom composition, bird use, SAV, surface mats, and water chemistry.***
    - ***Provide context to spur observations***
    - ***Information regarding year-to-year variability***
- Level I Assessment: Developing detailed maps of all wetlands surrounding GSL (UGS)
- ***Mapping Phragmites distributions on eastern shores of GSL (USU)***
    - ***Quantify changes surrounding discharge and put observed changes in perspective***

Nutrient Criteria Development

http://www.waterquality.utah.gov/nutrient/index.htm

- Survey of duck hunters about water quality values and concerns r/e GSL wetlands
- ***Exploring numerous multivariate approaches for identifying threshold responses***
- ***Exploring several techniques for removing the influence of covariates, both natural and human-caused, when evaluating nutrient effects***
- ***Developing methods for routinely measuring functional water quality indicators, including: Organic matter standing stocks, BOD responses to nutrient additions, SOD & OM relationships (U of U), stream metabolism, nutrient limitation, and leaf pack decomposition.***
    - ***Some of these techniques could be modified for Willard Spur investigations***
- ***Exploring the use of nutrient uptake models for site-specific standard development (USU)***
    - ***Could be applied to access canal (more later)***

Biological Assessments

- RIVPACS models for stream invertebrates; models generate species-specific predictions and account for natural environmental gradients
- ***Developing diatom assessment metrics (Rushforth Phycology)***
    - ***Could be modified for Willard Spur ongoing monitoring***

Ecological Risk Assessment: Mercury and Selenium

- Ongoing investigations to evaluate Hg and Selenium (USGS, USFWS, USU, UofU)

- Using ecological risk assessment approach to combine multiple lines of evidence for Hg Great Salt Lake Assessments
(see http://www.waterquality.utah.gov/WQAssess/documents/IR2010/Part2/AppxA-2_GSLHgPart2_2010.pdf)
    -

Water Quality Models

- Qual2K for Waste Load Analyses (USU)
- Exploring more robust models for lakes and reservoirs
- ***Genetic algorithms to assist with multiple parameter calibrations***
    - ***Techniques may be useful for Willard Spur water quality models as well***

Key Questions and Objectives

Potential Impacts of the POTW Discharge

What are the most limiting (sensitive) conditions within Willard Spur?

- Growth season vs. period of macrophyte senescence

What are the dynamics of nutrient storage and transport within Willard Spur? Seasonal Variation? Year-to-year storage of available nutrients within sediment?

What nutrients are limiting primary production within the Spur? Does this vary seasonally?

What role do macrophytes play in the retention and transport of nutrients within Willard Spur?

Development of a Long-Term Monitoring and Assessment Strategy

What are the key indicators of biological integrity?

What management options will be employed under hypothetical future scenarios?

What changes to Utah's water quality standards, if any, are necessary to ensure the long term protection of aquatic life and recreation uses within Willard Spur?

Research Priorities: DWQ Perspective

Identify an Appropriate Water Quality and Hydrologic Model

- Refine data collection requirements
- Model will likely need to be modified to accommodate unique conditions within Willard Spur
- Ultimately could be useful for other purposes (e.g., WLA and evaluation of other proposed projects (GSL Mineral expansion)

Evaluate Candidate Condition Indicators for Long-term Monitoring and Assessment Efforts

- Refine collection requirements
- Provides information related to the goal of establishing appropriate long-term protections for the Willard Spur ecosystem
- Creates a process whereby we can establish an adaptive management framework to account for uncertainty
- Need to establish criteria for ranking potential candidates (e.g., CA Estuary Report)

Develop a Detailed Plan for the Analysis and Interpretation of Empirical Water Quality and Biological Data

- Some can be done by DWQ and Panel members, but may need to rely on contractors for the "heavy lifting" due to human resource contraints

Evaluate Nutrient Uptake in Boat Access Channel

- Empirical measure of uptake rates will help evaluate water quality models
- Can directly evaluate whether plant effects, if any, are locally confined or likely to have larger effects
- Opportunity to capture baseline conditions before the discharge point is moved (if it is moved)

Evaluate the Export of water, nutrients and Organic Matter from Willard Spur

- Establish flow gage
- Refine discharge measurement methods
- Deploy bedload sampling devices during autumn and spring "high-flow" events to capture exports of OM

Field and/or Laboratory Experiments to Evaluate Macrophyte Effects on Nutrient Storage and Transport

- Include storage within sediment
- Evaluate how nutrients are released into water column during senescence
- Consider nutrient storage within tubers

Evaluate the Potential of Using Existing Satellite Imagery

- There are significant year-to-year changes within the spur and this is our only long-term record
- Should consult with remote sensing expert about what data could potentially be obtained to inform our evaluations
- Could potentially be useful to evaluate other wetlands around the lake

Attachment 2

Kettenring notes for Willard Spur Science Committee meeting 22 September 2011

How does your work as a scientist link to or help address the elements, linkages, and/or factors in the draft conceptual models?

My work focuses on what drives the population and community dynamics of native and invasive wetland plant species. Both seem of interest here but I will mostly focus on this from an invasive plant perspective – mostly *Phragmites* because that is the biggest invasive plant issue in Great Salt Lake wetlands.

The most important abiotic factors that drive changes in wetland plant populations and communities (abundance, composition, productivity, etc.) include nutrient levels (N, P), water levels, and salinity levels. Biotic factors that control wetland plant communities include herbivory (e.g., by birds or grazers) and competition (including from invasive plants).

Most of my recent work has focused on *Phragmites* and what drives its invasion. Nutrients, water levels, and salinity are all factors known to affect *Phragmites*, with different factors mattering more or less at different life stages (seeds, seedling, sprouts from rhizomes, adult plants):

- seeds generally require low water, low salinity, and high light for germination. Nutrients do not have a big affect on whether a seed germinates.
- seedlings respond favorably to high light, high nutrients, low salinity, and low water levels
- rhizome sprouts (rhizomes are for clonal spread – they are underground stems) are less affected by nutrients and are more affected by salinity and then light levels (water levels matter only in the context of limiting light)

So these are general patterns that we know based on work done in other places (particularly the Atlantic coast). We don't have good numbers on how much is too much or too little to favor *Phragmites* growth and spread, particularly exponential growth and spread. That is where research can come into play (e.g., what nitrogen and phosphorous levels contribute to rapid *Phragmites* seedling growth compared with ambient nutrient levels? Are there threshold levels?).

Phragmites can spread both by seed and rhizomes. Recent research that we've conducted suggests that most spread is by seeds except within patches (i.e., very short distances). These patterns have both benefits and drawbacks in terms of *Phragmites* management. Seeds and seedlings are more fragile than rhizomes (i.e., require more specific conditions for germination and establishment) BUT individual plants can produce thousands of seeds which can disperse easily by wind. There are huge *Phragmites* seed sources near Willard Bay – both at Harold Crane WMA and the Bear River Migratory Bird Refuge, among other places. So if we create prime habitat for *Phragmites* seedlings in the Willard Spur by providing lots of nutrients, then we are in trouble. Also, previous work I did in the Chesapeake Bay shows that with higher nitrogen and phosphorous levels, *Phragmites* can produce orders of magnitude more seeds. So not only do seedlings do well under higher nutrient conditions but adult plants also produce lots more seeds. *Phragmites* rhizomes are more durable and can break off and float to other places. When they get lodged in some soil, they can easily sprout and grow rapidly. BUT this spread requires (1) the rhizomes to break off from existing *Phragmites* stands which likely only occurs with a major disturbance and (2) that there is water for these rhizomes to float elsewhere.

You might ask why we care at all about *Phragmites*. Here are three reasons:

(1) It is a very aggressive species that essentially out-competes any native plant that it encounters as well as invades open water habitats. So we lose native plant diversity. That said, we don't know how rapidly *Phragmites* spreads in the GSL nor what exactly it is replacing.

(2) Loss of native plants means severe alterations of habitat. Since these wetlands are prime habitat for migratory waterfowl and shorebirds, *Phragmites* invasion may severely impact habitat quality. *Phragmites* is so dense that few things can move through it. Its seeds are not very nutritious compared to what it replaces, particularly alkali bulrush (*Schoenoplectus maritimus*), one of the main plants that managers target. That said, we don't have good data on bird use of native plants such as alkali bulrush vs. *Phragmites* (or at least I don't know about it – I saw something about Audubon surveys…)

(3) It alters nutrient cycling in wetlands – particularly with respect to nitrogen dynamics. I have no idea how this might come into play here in our wetlands – the work was done elsewhere and I don't know if it is applicable here or not (I would need to go back and read previous studies to know).

What key objectives do we need to achieve, i.e., questions do we need to answer, to address the program objective? (how you might design this research program)

- Determine current composition of wetland vegetation in Willard Spur (this is something I am currently doing with Christopher Neale with remotely sensed images)
- Determine what is desirable composition of native plant species vs. *Phragmites*
    - Determine how much *Phragmites* is too much based on societal value, habitat needs of migratory birds, and other factors
    - Determine if there is a threshold amount of *Phragmites* past which there is no turning back
- Determine what conditions promote *Phragmites* invasion in these areas – look at interaction of nutrients * water levels * salinity for seed germination / seedling establishment vs. rhizome sprouts (the different ways that *Phragmites* can invade) and identify thresholds.
- Determine how *Phragmites* stands might expand by rhizomes or spread by seeds once established under different environmental conditions (nutrients * salinity * water levels) and identify thresholds. For instance, clonal spread (rhizomes) might be impacted little by these abiotic factors while seed reproduction may mostly be impacted by nutrients.
- Determine how native vegetation and *Phragmites* has changed historically in the Willard Spur and whether there are any relationships with changes in water levels, salinity, or nutrients
- Determine how wildlife (mostly birds) use wetland vegetation and the trade-offs between *Phragmites* and other species of interest like alkalki bulrush (*Schoenoplectus maritimus*)
    - Determine what you lose when *Phragmites* take over vs. open water or native plants in terms of habitat quality, diversity of fauna, etc.
- Determine what are reasonable reference sites for the Willard Spur – to know what is possible, desirable, etc.
- Determine what are good indicators of wetland condition

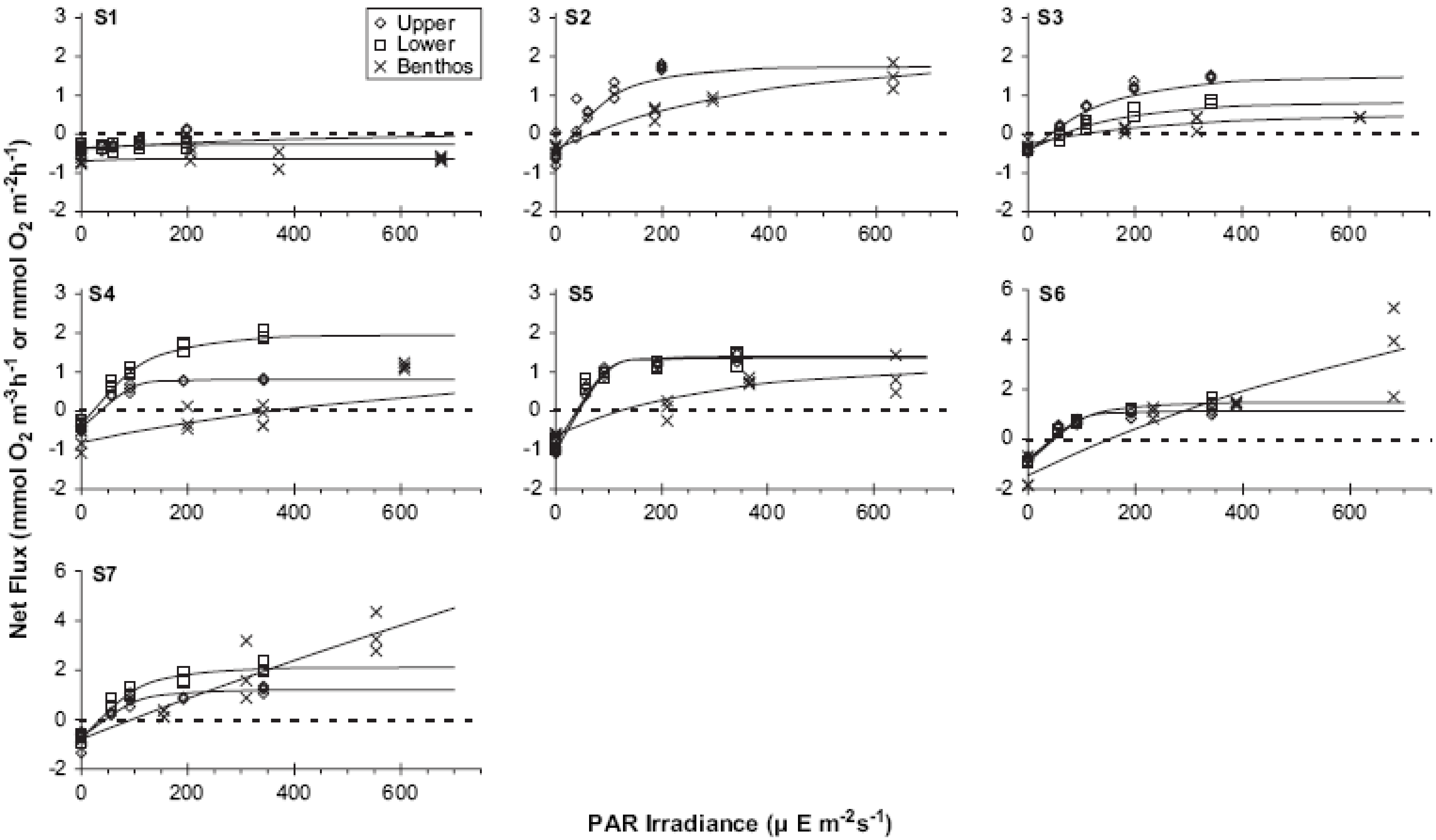
What studies do you recommend as the most critical to addressing the objectives of the program? How would you prioritize them?

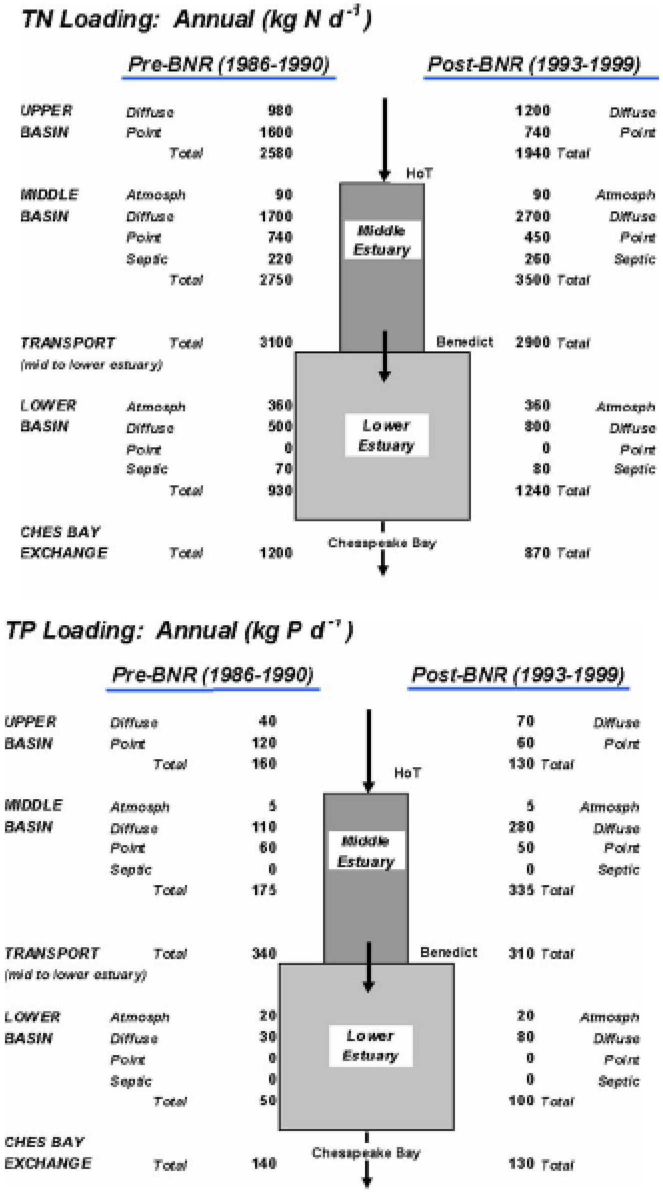
It's hard for me to rank things without seeing the big picture – what other people are suggesting.

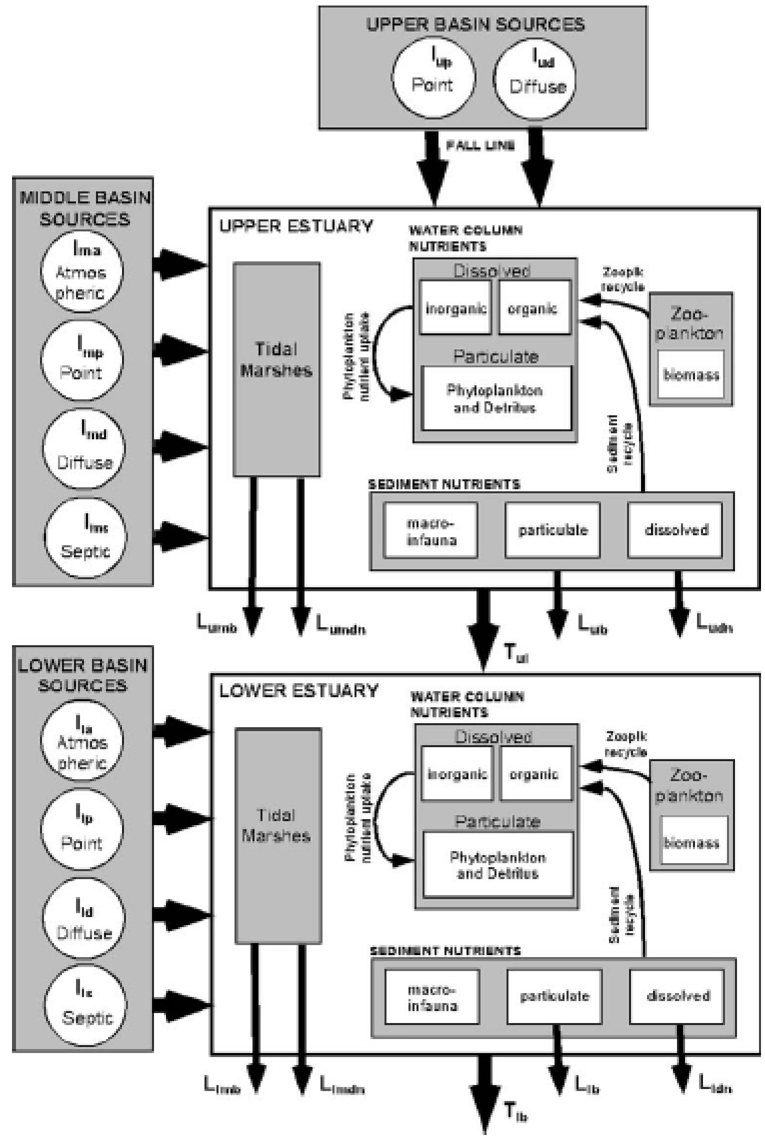
Here are some general approaches for how I might address some of the objectives above:

(1) Analysis of historical images and environmental data where available to look at relationships between vegetation and abiotic conditions
(2) Ecological experiments under controlled environments – growth chambers, mesocosms in greenhouses or common garden setting to look at abiotic factors (nutrients, salinity, water levels) and their affects on different life stages of *Phragmites*, and particularly identify thresholds
(3) Spatially explicit modeling of vegetation dynamics (including *Phragmites*) in Willard Spur under different abiotic conditions (incorporating data from (1) and (2).)
(4) Field surveys to evaluate habitat use of different vegetation types.

Attachment 3


S1
S2
S3
S4
S5
S6
S7
Upper
Lower
Benthos
Net Flux (mmol O2 m-3h-1 or mmol O2 m-2h-1)
PAR Irradiance (μ E m-2s-1)


TN Loading: Annual (kg N d-1)
Pre-BNR (1986-1990)
Post-BNR (1993-1999)
UPPER BASIN
Diffuse 980 1200 Diffuse
Point 1600 740 Point
Total 2580 1940 Total
HoT
MIDDLE BASIN
Atmosph 90 90 Atmosph
Diffuse 1700 2700 Diffuse
Point 740 450 Point
Septic 220 260 Septic
Total 2750 3500 Total
Middle Estuary
TRANSPORT (mid to lower estuary)
Total 3100 2900 Total
Benedict
LOWER BASIN
Atmosph 360 360 Atmosph
Diffuse 500 800 Diffuse
Point 0 0 Point
Septic 70 80 Septic
Total 930 1240 Total
Lower Estuary
CHES BAY EXCHANGE
Total 1200 870 Total
Chesapeake Bay
TP Loading: Annual (kg P d-1)
Pre-BNR (1986-1990)
Post-BNR (1993-1999)
UPPER BASIN
Diffuse 40 70 Diffuse
Point 120 60 Point
Total 160 130 Total
HoT
MIDDLE BASIN
Atmosph 5 5 Atmosph
Diffuse 110 280 Diffuse
Point 60 50 Point
Septic 0 0 Septic
Total 175 335 Total
Middle Estuary
TRANSPORT (mid to lower estuary)
Total 340 310 Total
Benedict
LOWER BASIN
Atmosph 20 20 Atmosph
Diffuse 30 80 Diffuse
Point 0 0 Point
Septic 0 0 Septic
Total 50 100 Total
Lower Estuary
CHES BAY EXCHANGE
Total 140 130 Total
Chesapeake Bay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FALL LINE
MIDDLE BASIN SOURCES
Ima Atmospheric
Imp Point
Imd Diffuse
Ims Septic
UPPER ESTUARY
WATER COLUMN NUTRIENTS
Dissolved
inorganic
organic
Particulate
Phytoplankton and Detritus
Phytoplankton nutrient uptake
Zooplk recycle
Zooplankton
biomass
Tidal Marshes
Sediment recycle
SEDIMENT NUTRIENTS
macro-infauna
particulate
dissolved
Lumb
Lumdn
Tul
Lub
Ludn
LOWER BASIN SOURCES
Ila Atmospheric
Ilp Point
Ild Diffuse
Ils Septic
LOWER ESTUARY
WATER COLUMN NUTRIENTS
Dissolved
inorganic
organic
Particulate
Phytoplankton and Detritus
Phytoplankton nutrient uptake
Zooplk recycle
Zooplankton
biomass
Tidal Marshes
Sediment recycle
SEDIMENT NUTRIENTS
macro-infauna
particulate
dissolved
Llmb
Llmdn
Tlb
Llb
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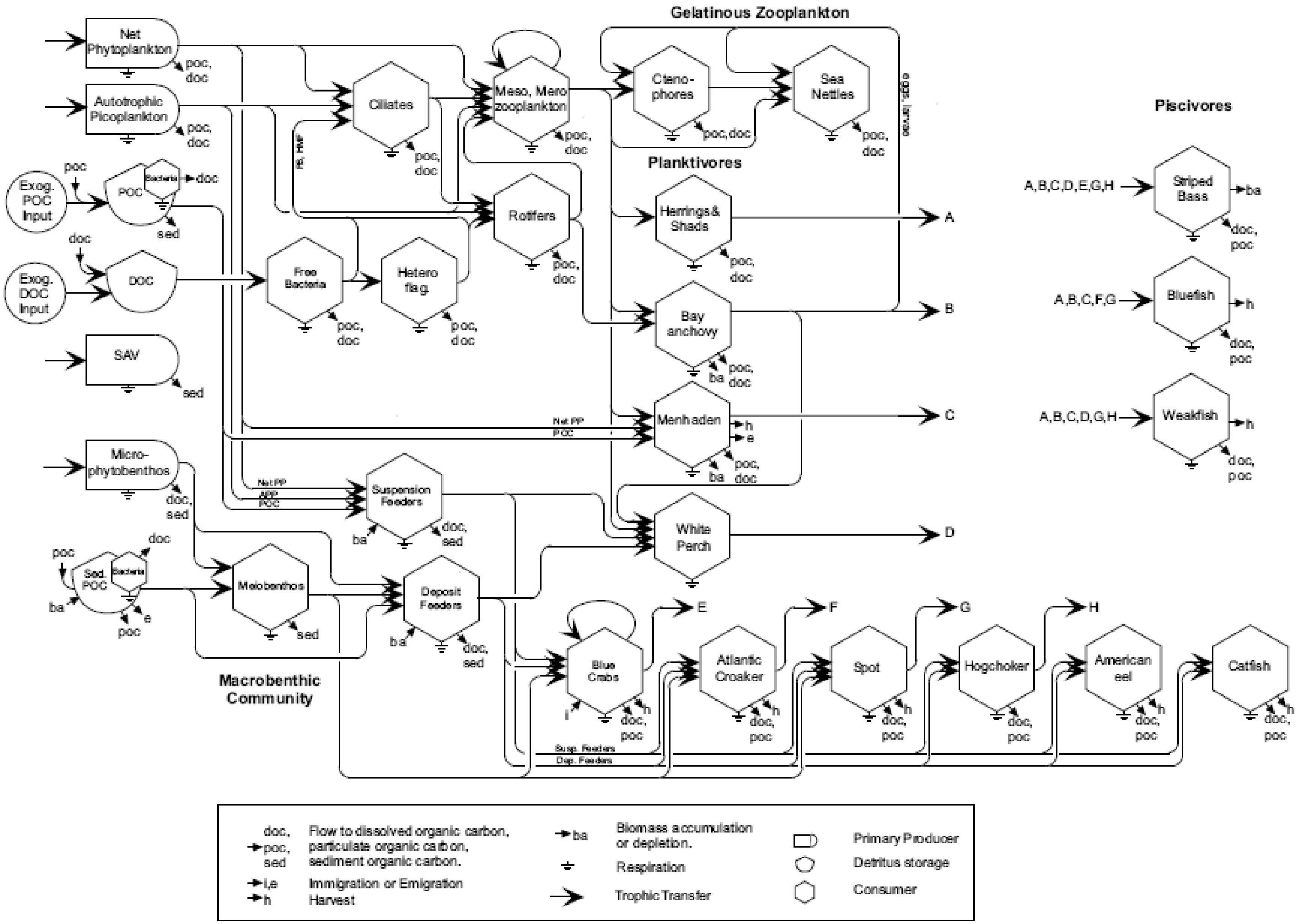

Gelatinous Zooplankton
Net Phytoplankton
Autotrophic Picoplankton
Exog. POC Input
POC
Bacteria
Exog. DOC Input
DOC
SAV
Micro-phytobenthos
Sed. POC
Ciliates
Meso, Mero zooplankton
Cteno-phores
Sea Nettles
eggs, larvae
Rotifers
Free Bacteria
Hetero flag.
Planktivores
Herrings& Shads
Bay anchovy
Menhaden
Net PP
POC
APP
Suspension Feeders
White Perch
Meiobenthos
Deposit Feeders
Macrobenthic Community
Blue Crabs
Atlantic Croaker
Spot
Hogchoker
American eel
Catfish
Susp. Feeders
Dep. Feeders
Piscivores
A,B,C,D,E,G,H
Striped Bass
A,B,C,F,G
Bluefish
A,B,C,D,G,H
Weakfish
A
B
C
D
E
F
G
H
poc, doc
doc, poc
doc, sed
sed
ba
h
e
i
doc, poc, sed
Flow to dissolved organic carbon, particulate organic carbon, sediment organic carbon.
i,e
h
Immigration or Emigration
Harvest
ba
Biomass accumulation or depletion.
Respiration
Trophic Transfer
Primary Producer
Detritus storage
Consumer

Table 2
Diet matrix for winter 1994 in Goose Creek Bay, St. Marks National Wildlife Refuge, FL

Prey number	Diet Composition as percentage of total ingestion of predator (designated by#)																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		65	8					1					9.5	9.5											
2		5	4										3	3											
3			3					9					10			16.9						1	9	33	43
4					47		14																		
5					3		6																		
6										3						8		66			23.1	2	4	30	6
7										0.5														0.5	
8										7	74						5								
9																									
10											1					3	0.5							3.5	
11																									
12																				20				13	
13																					8.5				
14										1.5						6.6		34		1	13	1	2	17	3
15											5					2.5				10	2.5				
16											0.5									27	7				
17																									
18																									
19																									
20											0.5														
21																									
22																									
23																									
24																									
25																			2				1		
26																	2		98	41	26		11		
27											9														
28																									
29										4.5						18									
30																									
31																									
32																									
33										2.6						14.1	1.5				10				5.5
34										0.9						7					4				2
35																1.9					1				0.5
36																				1		1	1	3	16
37																									
38																									
39																									
40																									
41																									
42																									
43						10			90	25		50			50	1	1								
44						30			5	5		50			50	6									
45			25																			81	56		
46		20				29		45	5				37.5	37.5								7			23
47			60	100	40		80														4.9				
48	100	10			10	31		45		50			40	50		15						7	16		1

Attachment 4

Most Critical Research for Willard Spur

J. Hagy, 9/22/2011

Task #1: Nutrient Budgets

Research Question(s):

What is the relative magnitude of N and P sources to the Willard Spur? Under what conditions are anthropogenic nutrient sources significant? When, if ever, is the load from the Willard/Perry plant quantitatively important? If the plant or other anthropogenic sources are not currently important, could any reasonable expectation for future increases change this conclusion?

Why Important:

600,000 gallons of sewage per day might fill a convoy of 80 tanker trucks driving down the interstate! This may seem like a lot, but relative magnitudes can be difficult to comprehend without a full appraisal of the magnitude of other sources of water and nutrients to the ecosystem. To comprehend the significance of any anthropogenic input to Willard Spur, it is essential to be able to place each flux in a comparative context.

Research Approach:

Characterize the different hydrologic regimes that occur and develop a nutrient budget for N and P for each regime. These may be associated with seasons, but may also transcend seasons. The nutrient budget should characterize major N and P inputs, internal fluxes, and exports associated with each regime. Inputs could include: (a) riverine inputs or other inputs associated with hydrologic flows, (b) atmospheric deposition, (c) point sources. Internal fluxes could include: (a) sediment/water nutrient fluxes, (b) seasonal uptake and release of nutrients by submersed and emergent macrophytes, (c) nutrient flux associated with waterfowl (?). Losses could include permanent burial (N and P), denitrification (N), export via waterfowl (?). Net exchange at the boundary with GSL should be included in the budget and could be a net export or import. It may be useful to characterize seasonal storage and release of nutrients within sediments and plant biomass and express these an export from one season and an import to another season.

Related References:

Boynton, WR, JH Garber, R Summers, and WM Kemp. 19995. Inputs, Transformations, and Transport of Nitrogen and Phosphorus in Chesapeake Bay and Selected Tributaries. Estuaries 18(1B): 285-314.

Boynton, WR, JD Hagy, JC Cornwell, WM Kemp, SM Greene, MS Owens, JE Baker and RK Larsen. 2008. Nutrient budgets and management actions in the Patuxent River estuary, Maryland. Estuaries and Coasts. 31: 623-651

Task #2: Food Webs

Research Question(s):

What ecological attributes and functions are essential to supporting the migratory waterfowl that utilize the Willard Spur? Given that the designated uses specifically identify supporting trophic relationships (i.e., "associated food chain"), how can we characterize the food web of the Willard Spur in general, and more specifically, the trophic pathways that ultimately support the migratory waterfowl populations? Is the bird population at the Willard Spur potentially limited by food availability?

Why Important:

EPA efforts to develop numeric nutrient criteria for water of Florida have illustrated how essential it is to identify nutrient sensitive biological endpoints and quantitative indicators of support for those endpoints. Development of numeric criteria for the Willard Spur will also require identifying nutrient sensitive biological endpoints and quantitative measures that may relate their status to nutrients. In the case of the Willard Spur, migratory waterfowl are an important designated use, as is the food chain that supports them.

Research Approach:

Quantify the food web of the Willard Spur with an emphasis on understanding and quantifying the trophic pathways that support migratory waterfowl. Begin by characterizing the magnitude and species composition of the migratory waterfowl assemblage. Characterize their bioenergetics, including daily ration and diet preferences. Characterize trophic relationships more broadly by working backwards, ultimately linking waterfowl production to the various primary producers within the Willard Spur (e.g., SAV, macroalgae, epiphytes and microphytobenthos, emergent macrophytes). Begin with the assumption that an initial estimate can be made based on existing information and general ecological principles (i.e., "rules of thumb."). Subsequently, reduce uncertainty by gathering new data and then updating the food web model. If helpful, use available food web modeling software such as Ecopath with Ecosim (www.ecopath.org).

Related References:

Christian, RR and J. Luczkovich. 1999. Organizing and understanding a winter's seagrass foodweb network through effective trophic levels. Ecological Modelling. 177: 99-124.

Hagy, JD and WM Kemp. 16. Estuarine Food Webs. In: Day, JW and WM Kemp (eds). Estuarine Ecology, Second Edition. Wiley. (in press).

Hagy, JD. 2001. Eutrophication, hypoxia and trophic transfer efficiency in Chesapeake Bay. Dissertation. University of Maryland. (Chapter 6: A network analysis of mainstem Chesapeake Bay food webs during summer: eutrophication effects on carbon transfer efficiency to fish)

Task #3: Eutrophication Responses

Research Question(s):

What are the primary responses of the Willard Spur ecosystem to nutrient enrichment? How might these secondarily impact aquatic life uses?

Why Important:

If anthropogenic nutrient sources could be quantitatively significant (i.e., Task #1), and critical aquatic life uses could be affected by changes in key ecosystem functions (e.g., trophic controls on waterfowl, Task #2), it will be important to describe the mechanisms whereby nutrient enrichment could impact important ecosystem functions. This could lead to quantitative relationships, potentially explored in the context of dynamic simulation models.

Research Approach(es):

Many different kinds of measurements and/or experiments could provide insight into how nutrients impact ecological function on the Willard Spur. Possibilities include conducting local nutrient enrichment experiments. If spatial gradients in nutrient exposure are present, it might be useful to examine gradients of nutrient response. Abundance of macroalgae could be a useful indicator of nutrient exposure. An additional indicator is elemental composition, which may shift in relation to nutrient availability. Macroalgae can take up more nutrients (i.e., "luxury uptake") when nutrients are available at higher concentrations. SAV can do this as well. It may also be useful to examining nutrient effects on oxygen status and dynamics, particularly 24-hour minima and oxygen profiles from the water surface, through the SAV canopy to the sediment-water interface. Metabolic rates could be explored via open water metabolism techniques. Alternative, the shallow water may be especially favorable for quantifying metabolic rates using domes.

Related References:

Murrell, MC, JG Campbell, JD Hagy III, and JM Caffrey. 2009. Effects of irradiance on benthic and water column processes in a Gulf of Mexico Estuary: Pensacola Bay, Florida, USA. Estuarine, Coastal and Shelf Science. 81: 501-512.

Devereux, R., DF Yates, J. Aukamp, RL Quarles, SJ Jordan, RS Stanley, and PM Eldridge. 2011. Interactions of Thalassia testudinum and sediment biogeochemistry in Santa Rosa Sound, NW Florida. *Marine Biology Research* 7: 317-331.

Caffrey, JM. 2003. Production, respiration and net ecosystem metabolism in US Estuaries. *Environmental Monitoring and Assessment* 81: 207-219.