Modelling long-term storm loss and restoration of the aquatic plant *Vallisneria americana* in the Hudson River estuary

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Background

Submerged aquatic vegetation (SAV) in the Hudson River estuary have important ecosystem functions

- SAV has in recent history occupied up to 6% of the estuary area or 1802 hectares (Findlay et al 2014)
- It increases dissolved oxygen in the river and acts as a habitat for fish and invertebrates increasing productivity
- The majority of SAV in the estuary is the native *Vallisneria americana*
- The Hudson River estuary in New York state is severely impacted by human-induced change through pollution, physical change and invasive species

Two storms in 2011 wiped out >90 % of V. americana

- Hurricane Irene and Tropical Storm Lee produced 38 to 68 cm of precipitation over Hudson Valley and washed 2.8 million tons of sediment into the estuary (Ralston et al. 2013)
- In 2012 sampling by volunteers showed a drastic decrease of all SAV, including *V. americana.* and recovery in 2013 and 2014 have been very slow (Strayer et. al. 2014)
- Burial of tubers in new settled sediment and decreased light availability for tuber production are suggested as the mechanisms of loss of the plant

Restoration is being discussed but there are issues of cost, sustainability and the longevity of restored areas

+ SAV in Hudson is relatively well surveyed and monitored (Findlay et al 2014)
+ Restoration is being discussed among managers and scientist, mainly to benefit fish spawning in the river
- Storms are naturally recurring and may be strengthened by climate change (IPCC 2013) and longevity of restoration may not be guaranteed
- Costs to restore are high and funds could potentially be used for alternative measures to increase SAV such as riparian reforestation, agricultural best practice implementation or improved sewage treatment to decrease nutrient input into the estuary.

Objective, method & data

Objective: Create a long-term model to study the impact of storms and restoration

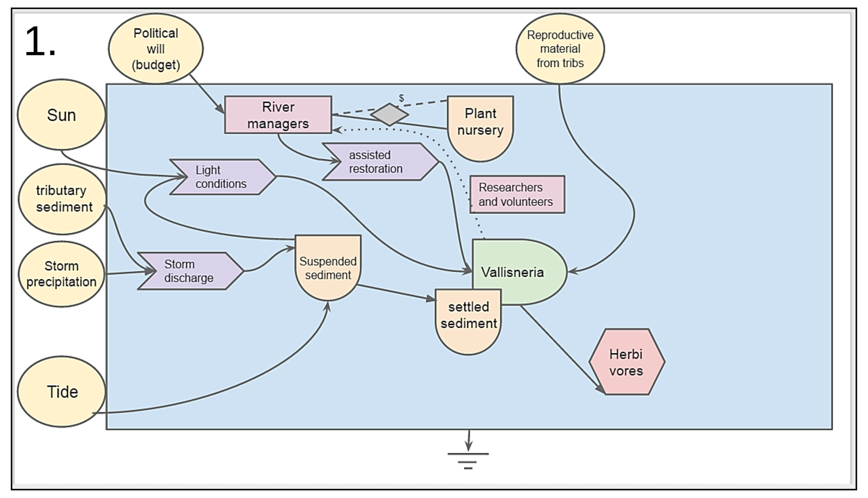
Method: Using an iterative process of increasing complexity, the system can be modeled graphically with a STELLA diagram of stocks, flows and connectors

Model uses data from experiments, literature, monitoring

- Sediment burial data from field experiments
- Climate data from IPCC and storm data from NOAA
- Light data from CIES monitoring and growth data from literature
- Restoration data & assumptions from literature and interviewed experts

Iterative modeling

1.



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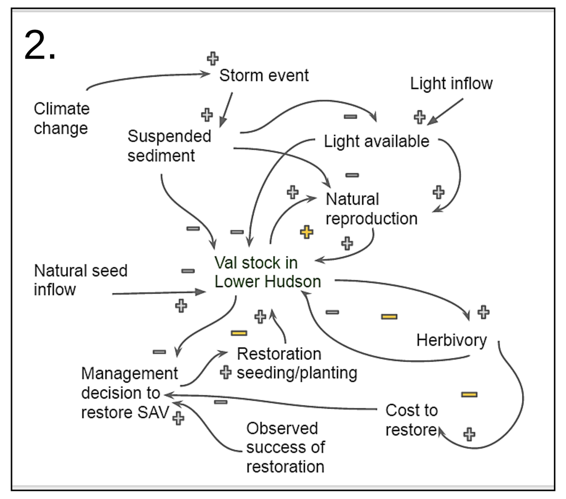
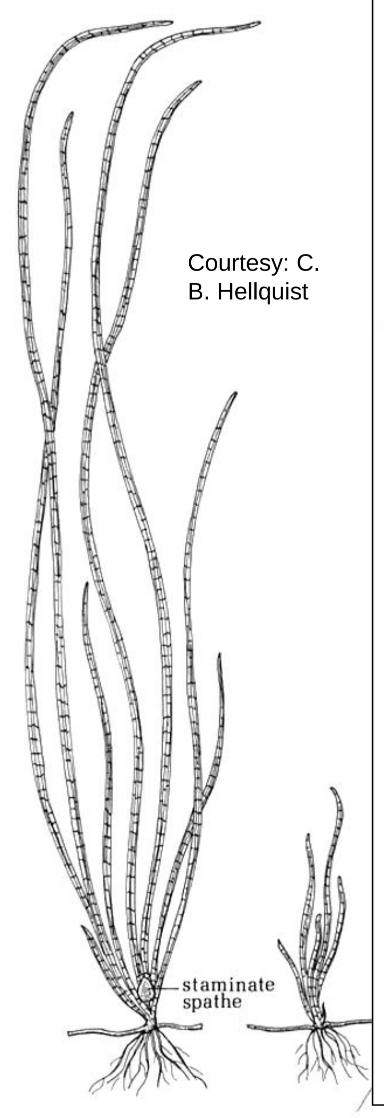


(1) Odum energy diagram outlines important causal links of energy transfer in the ecosystem. (2) Feedback loop diagram examines self-reinforcing and limiting loops in the system that may cause issues in quantitative modeling. (3) Stella diagram enables quantitative modeling of climate-change affected storm impact through burial and light impact as well as restoration efforts between 2000 and 2100.



Courtesy: C. B. Hellquist

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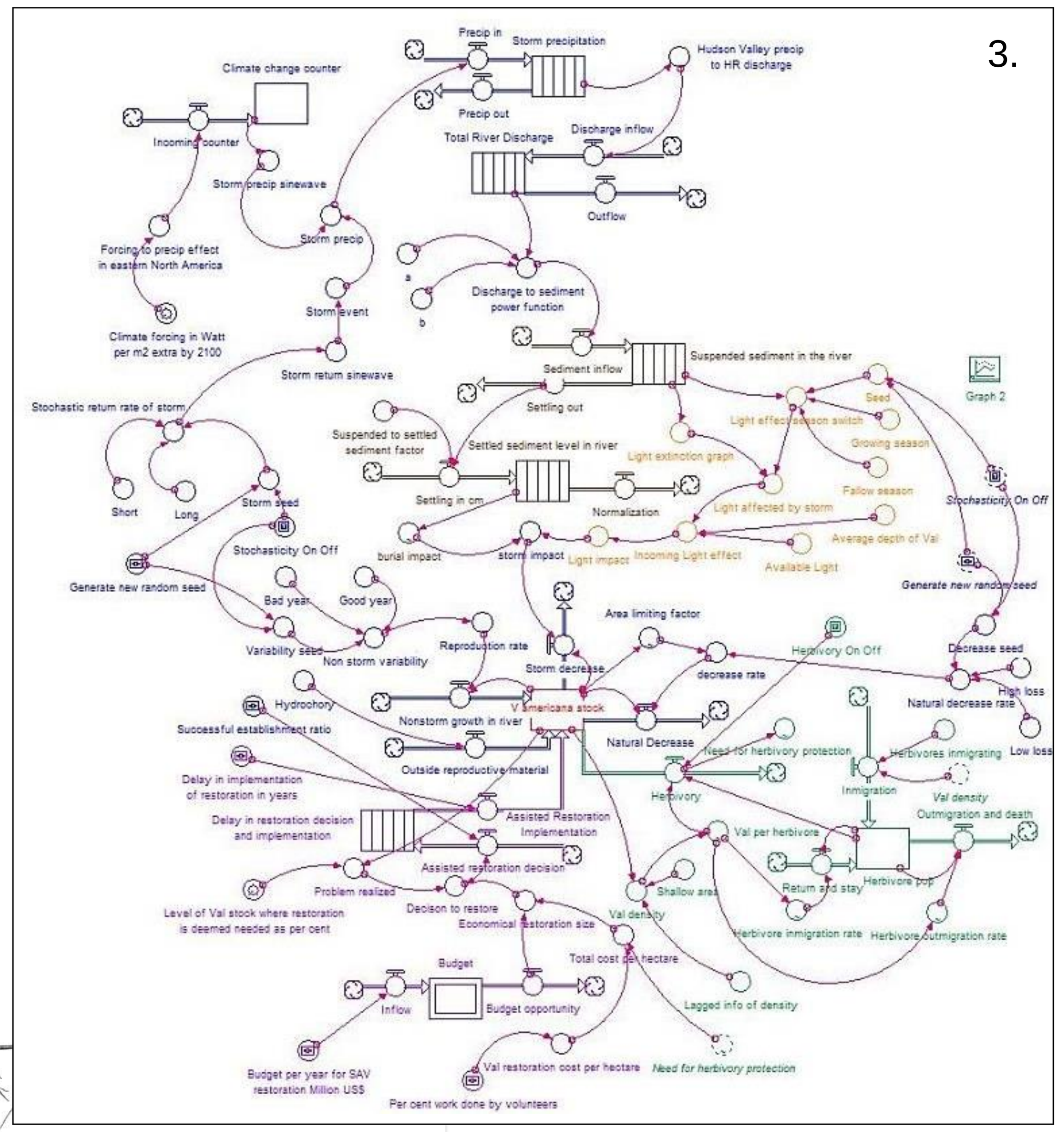
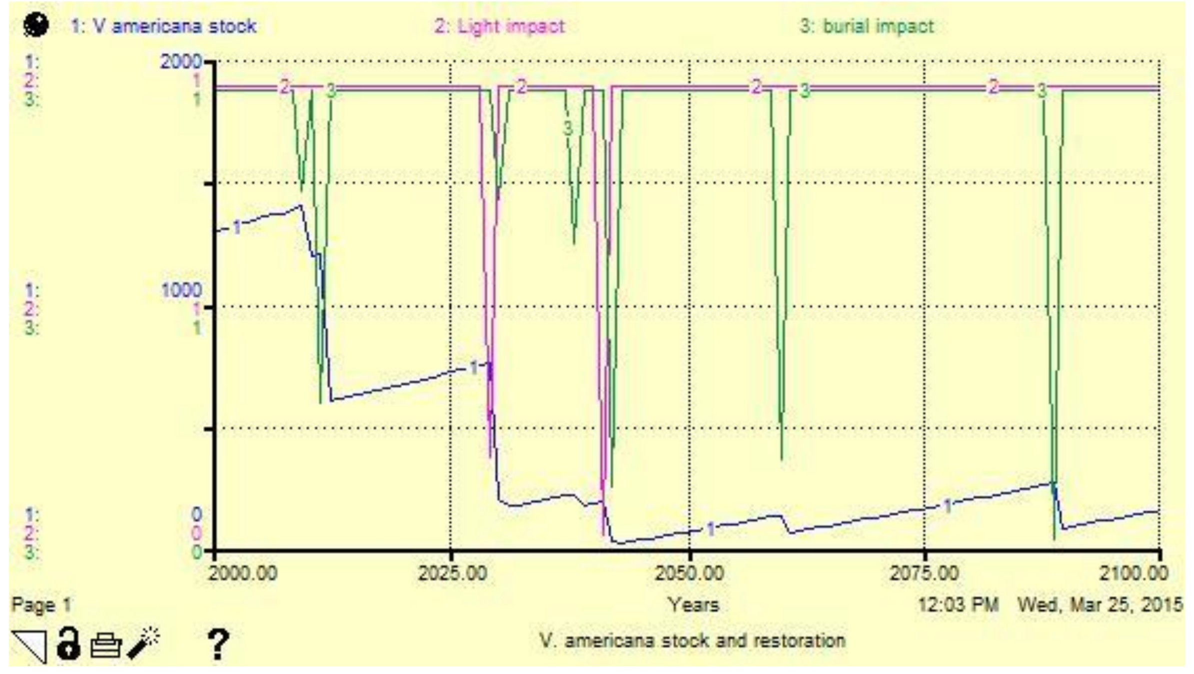


Results

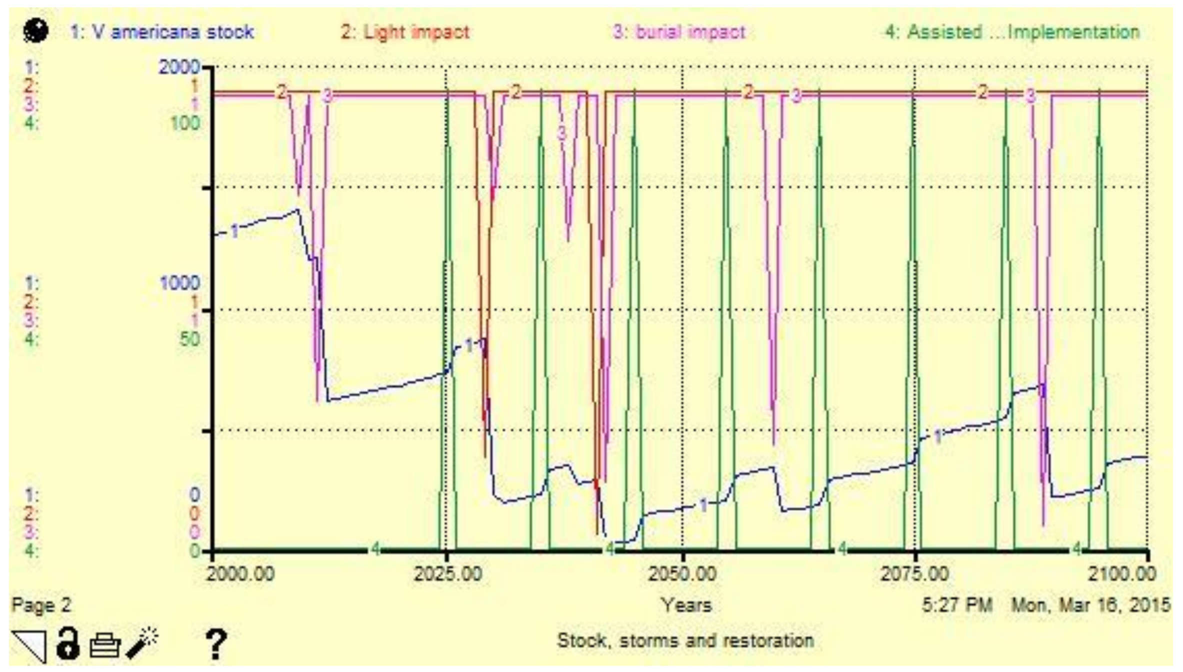
Non-restoration scenario results
- ~0-250 ha stock from 2040 onward
- Assumes climate forcing of 4.5 W/m²



Assumptions for all scenarios: Significant storm return time 20-30 years. 6.39 hectare establishment from hydrochory. Climate forcing impacts storm precipitation. Highest forcing scenario (8.5) of IPCC 2013 increasing storm precipitation by 20% by 2100. No significant impact from herbivory assumed.

Results cont.

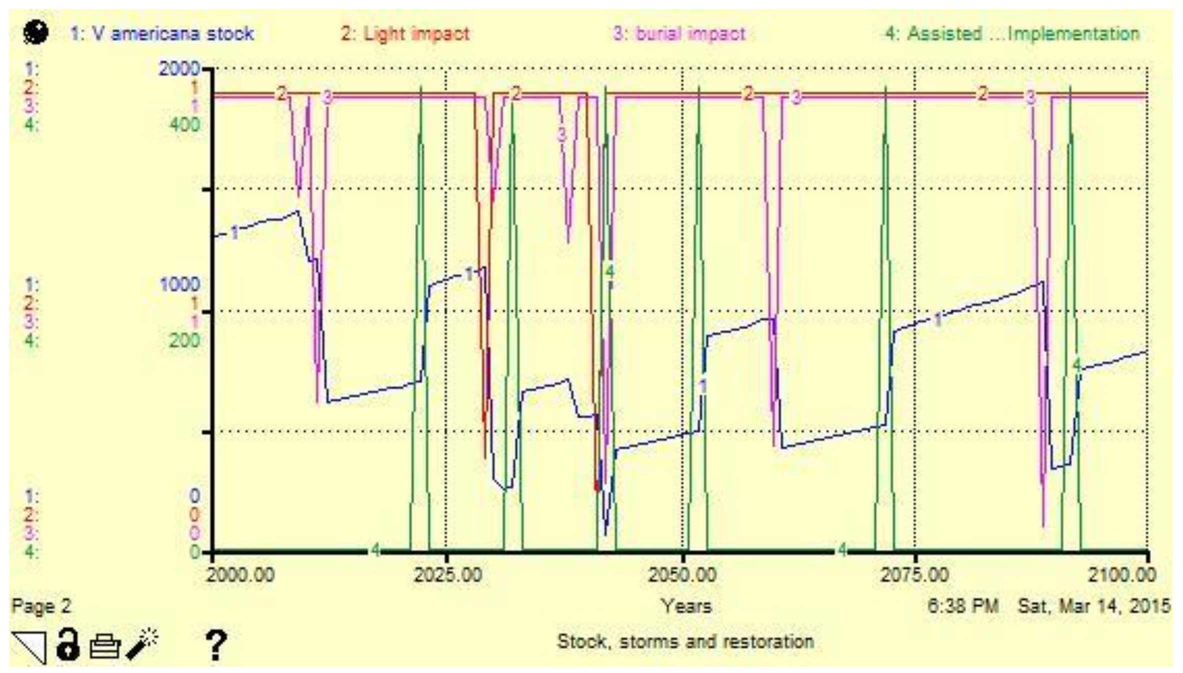
Baseline Restoration Scenario Results
- 8 restorations
- \$240m total
- 800 ha total restored
- ~0-600 ha stock from 2030 onward



Baseline vs Best-case scenario assumptions

- Climate forcing – 4.5 vs 2.6 W/m²
- Budget - \$3m vs \$5m per year
- Volunteer work 0% vs. 50 %
- Years to implement restoration – 5 vs 2
- Stock level to trigger restoration – 30% vs 40%
- Successful establishment – 75 % vs 100%

Best-case Scenario Results
- 6 restorations
- \$300m total
- 2400 ha total restored
- ~500-1000 ha stock



Conclusions

Restoration is possible but may be undone in next storm. Without restoration, no SAV? – Volunteers matter

- Large enough restoration to make a difference will be expensive (\$10's of millions per restoration opportunity)
- Volunteers increase possible restoration area
- Long-term models could potentially be used as a tool by managers and decision-makers
- Model could be adapted to other river systems and other aquatic plants

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