1867 THAYER SCHOOL OF ENGINEERING AT DARTMOUTH

Nutrient Balance Simulation in Small-Scale Recirculating Aquaculture

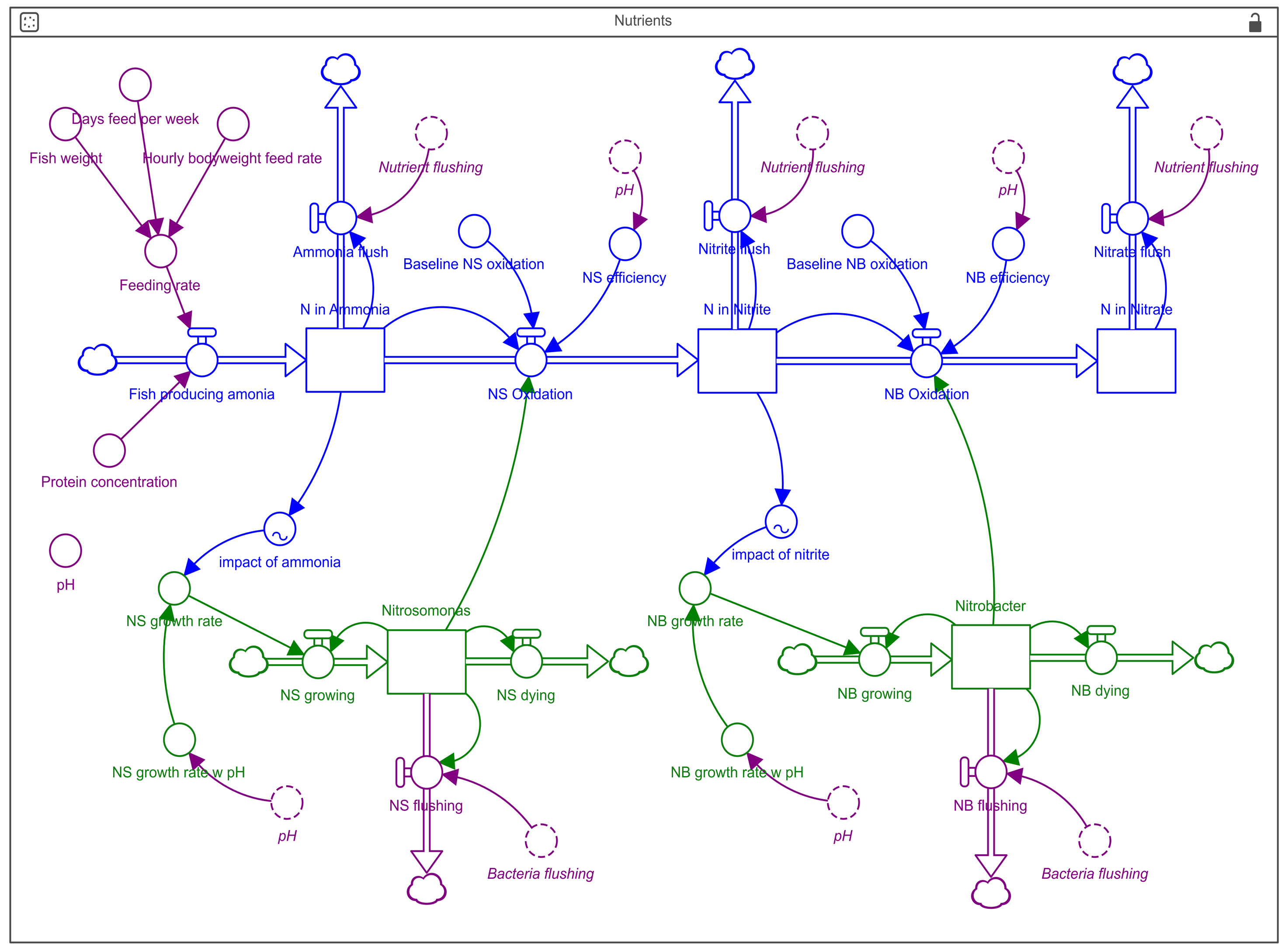
DARTMOUTH ORGANIC FARM

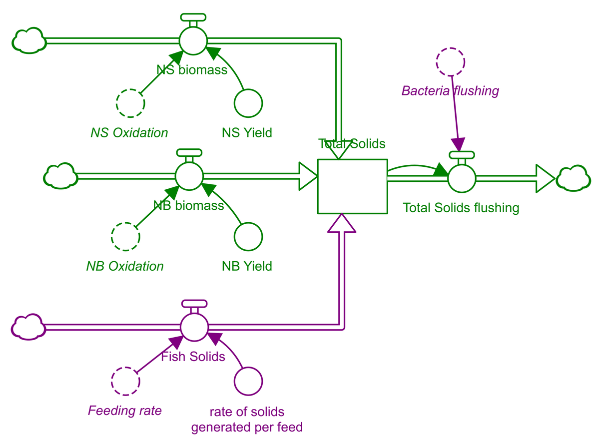
Introduction & Purpose

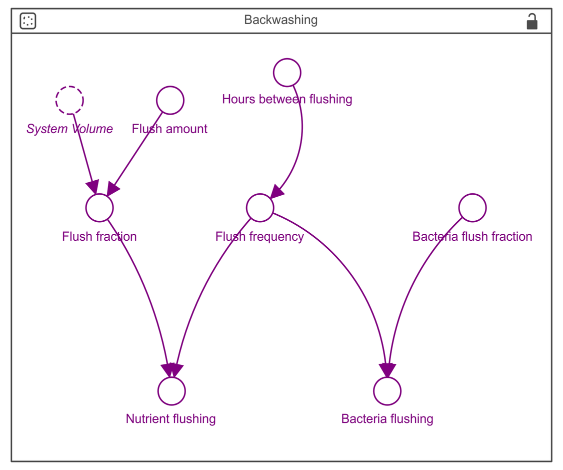
Over the next 35 years, worldwide agriculture will have to double in production to keep up with rising demands (Foley). Both small- and large-scale aquaculture are possible solutions, as they provide a potentially more energy and resource efficient way of producing protein. However, in addition to producing protein, aquaculture systems also produce excess nutrients that can be harmful to the fish if not properly managed.

Dartmouth's aquaculture lab is small enough to maintain these safe levels via bacterial breakdown and periodic flushing of the system. It employs bacteria from the genera Nitrosomonas, which oxidizes ammonia into nitrite, and Nitrobacter, which oxidizes nitrite into nitrate. This two-part process allows more nitrogen in the system, as nitrate is the least toxic. Every few days, a portion of the water is flushed and replaced with fresh water. This lowers nutrient concentrations and removed a portion of the bacteria biomass.

The purpose of this model is to understand the nutrient flow in the system in order to determine the optimal interval between flushes. Bacteria growth and activity are dependent on nutrient concentrations and other external factors, so the most important factors will be isolated and modeled.







Model Construction

The model has three main sections: nutrients (blue), bacteria (green) and solids (lower left box). The nutrients and bacteria are fed by the fish production of ammonia and drained as the system flushes (bottom right box).

Crucial features:

- Feedback between available nutrients and bacteria growth
- Mass balance of nutrients
- Nutrient input
- Flushing rate

Several assumptions were made about the system:

- pH = 8 (maintained with addition of bicarbonates)
- Temperature = 28 ˚ C
- Dissolved Oxygen = saturated

Testing

Two test criteria:

- Total weight of fish (proxy for nutrient input)
  - 1500g: large population of small fish
  - 5000g: smaller population of large fish
- Interval between flushes
  - 4 days
  - 10 days
- All models are shown to reach the steady state oscillation

Conclusions

This model produced the graphs below, which led to the following conclusions:

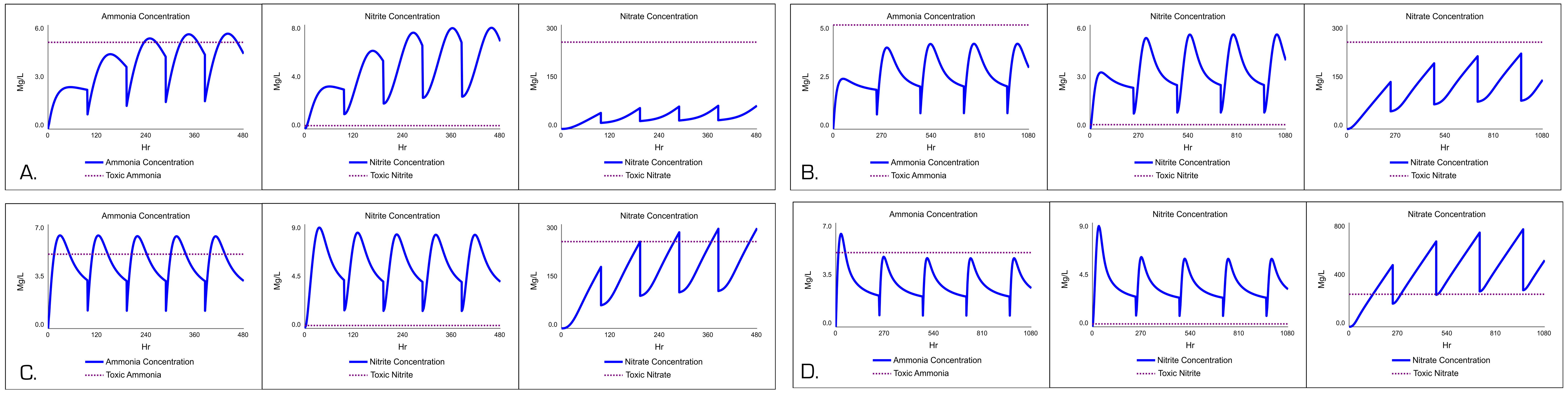
- 1500g fish: exceeds the toxic concentration of ammonia with short delay (A), but does not exceed either ammonia or nitrite with longer delay (B)
- 5000g fish: with short delay (C), both concentrations spend less time above toxic levels than long delay (D)

More importantly, nutrient concentration steady state is determined by flushing time and nutrient inflow, but the relationship between the two is not linear. Low fish and short delay exceeds toxicity, as does high fish and long delay, indicating an ideal balance between amount fish and delay of flushing. Further exploration into this relationship is necessary.

One important note is that for all the models, the concentrations of nitrite are above toxic levels. While the behavior of the concentration is correct, this model is missing a part crucial part of the nitrate behavior is yet unknown.

4 Day Flush Delay | **10 Day Flush Delay**

1500g Fish | **5000g Fish**



Run for 480 hours

Run for 1080 hours

Next Steps

- Research and include the missing factor in the nitrite concentration behavior. Levels shown here are much higher than reported levels.
- Incorporate a feedback between the nutrient concentrations and the flushing delay. Currently, the delay is a pre-assigned length but a feedback could allow the user to alter the delay depending on the nutrient build up.

References & Acknowledgements

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