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CIS 397

Aquaculture Simulation Report

Explanation:

Keeping fish, both as a pet and as livestock, requires care and attention to maintain their health due to various homeostasis requirements. For example, their environment is home to constantly changing chemicals and varying food sources, which can either restrain the organisms within it or cause them to flourish depending on the size of the environment as a whole. Manually keeping track of all these factors to ensure the survival of the fish is a tall task. So, instead of manually tracking the environment, and its effects, it has become necessary to simulate in the hopes of achieving a self-sustaining environment for fish that requires minimal intervention from outside sources.

The simulation itself works on many factors and assumptions. The entire simulation is based on the mathematical models simulating chemical cycling from the research paper "Mathematical and numerical modeling for a bio-chemical aquarium" by Riccardo Fazio and Alessandra Jannelli. Their model calculates the changing chemicals in an aquarium given various constants and functions that will be noted later on. Through these models, we built the foundation of a robust aquarium model where, with no intervention from fish or the user, the chemicals cycle as expected. With the chemicals in the aquarium cycling properly, we could consider the addition of fish and live plants into the ecosystem. While creating a fish class that contained all information necessary to simulate individual fish in a population, the simulation was able to include their weight, their health value, and their tolerance for concentrations of Ammonia and Nitrite. Furthermore, the simulation was also able to incorporate the chances that their next action is eating, urinating, defecating, or doing nothing. We modeled the probability of action based on the frequency of a tilapia fish. These values were found in the research paper "Tank Culture Tilapia" by James E Rakocy. Print statements were used to verify the frequency of events in the simulation match the real world data. The live plants were much less complicated. We implemented a list containing the normalized biomass of the plant population in the aquarium and the plant's growth rate. The population of the plants would impact the Nitrate and Oxygen production in the aquarium based on whether the plants were at their max biomass or they were completely eradicated. The use of both of these factors involved many assumptions, which will be listed below.

This culminated into the final product of the aquarium simulation. The user inputs data through prompts on the GUI. If the input is valid, then the simulation function is called. It interacts with the fish class, inputted tank size, inputted duration, chemicals, and plant population values saved in the simulation. This interaction is visualized by Figure 2 in the Diagrams, Plots, and Images section. At each time step, each fish object generates a random action that is then carried out. Upon the completion of the action, the chemical variables are updated. If the concentration of the chemicals is too high, then the fish's health decreases, and if their health reaches 0, then the fish dies. Otherwise, the simulation continues until we reach the duration specified by user input. At that point, a plot is created, and shown to the user. At the same time, if the user checked the box in the GUI, a .txt file of all the fish actions that took place is saved to the user's directory. This can be observed in Figure 2. The entire flow of the simulation can be observed in Figure 1 of the Diagrams, Plots, and Images section.

We found that given a 10,000 liter tank, with 10 tilapia starting as fry, their smallest size, we were able to achieve a self-sufficient aquarium for 3 months. The plots showcasing the output from this successful simulation can be observed as Figure 3 in the Diagrams, Plots, and Images section. While we have achieved a self-sufficient aquarium, it is worth noting that this result was reached through multiple assumptions. These assumptions can be observed below.

Once we obtained our results, it was time to validate them. This happened at many steps of the process. Upon completing the base chemical cycle, we compared our graph with the graph from the research paper to validate that our implemented mathematical models were correct. This can be observed with Figures 6 and 7 in the Diagrams, Images, and Plots Section. The figures are essentially identical, proving that our implementation was correct. At various steps of the coding process we used print statements at every opportunity to show the status of variables, the fish themselves, and the timestep of the simulation to ensure that everything was working as intended. If we ever encountered a case where an update broke the simulation, we could reference our dev branch on github that had a long series of rapid commits of the everchanging aquarium simulation. Validating the final output was difficult since we made many assumptions that drove the simulation forward past its initial state of cycling chemicals with no other factors of the aquarium. We were able to validate the fish actions via checking the fish action logs against their given action probabilities. Assuming our assumptions are true, and knowing that the fish actions and chemical cycling are valid, we can then assume the final output must also be valid.

As of right now, we have seen no evidence against our assumptions. So, a goal for the future is to investigate each of our assumptions to either prove or disprove their inclusion in the simulation. Reference our Expansion Ideas section for other ways that we intend to refine the simulation.

If you are exploring this document for the purpose of creating your own aquarium tank configuration, **do not assume that this simulation will 100% accurately model your configuration!** Use your own judgment as well as simulating your own data and parameters to decide whether or not you should use a specific tank set up.

Assumptions:

1. Fish poop a third of their body weight
2. Assuming a “moderate density” of plants is 12 plants at half their max length
3. Assuming that the plants are trimmed once they reach a “max length”
4. Assume plants grow at the same rate every second regardless of environmental factors
5. Assume plants don’t spread and reproduce
6. Assume that a day of high chemical concentrations kills fish
7. Assuming that the normalized plant population affects the p2 and p4 variables, such that:
    a. p2 = p2 * (.5 + plantBioMass)
    b. p4 = p4 * (.5 + plantBioMass)
8. The simulation starts after the tank has adjusted to nitrate cycle
9. Assuming fish pee 10 grams of ammonia per 100 pounds of fish
10. Assuming that max weight of tilapia is 1 lbs, or 440 grams (full grown)
11. Assuming that a month has 2,628,003 seconds
12. The fish do not reproduce, such that no interfishial relations take place.
13. Assume that the models work given wishbones (it was never described).
14. t functions from the research paper work (it was never described).

Diagrams, Images, and Plots:

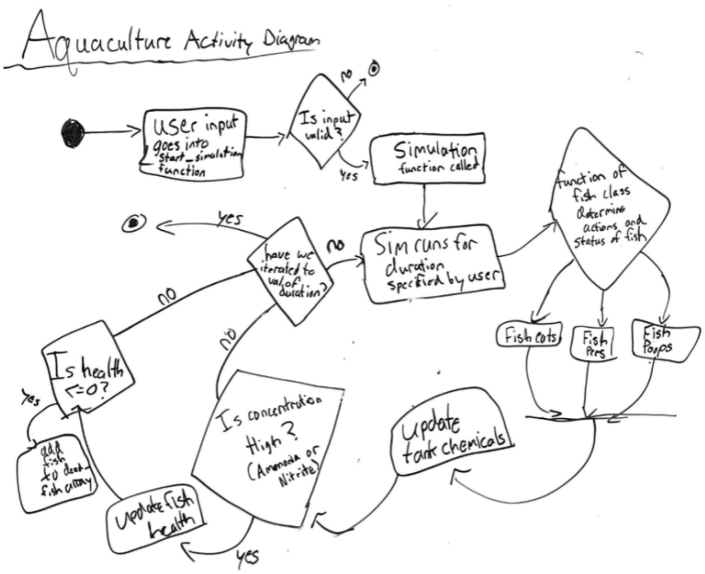

Figure 1: Activity Flow Diagram of Simulation

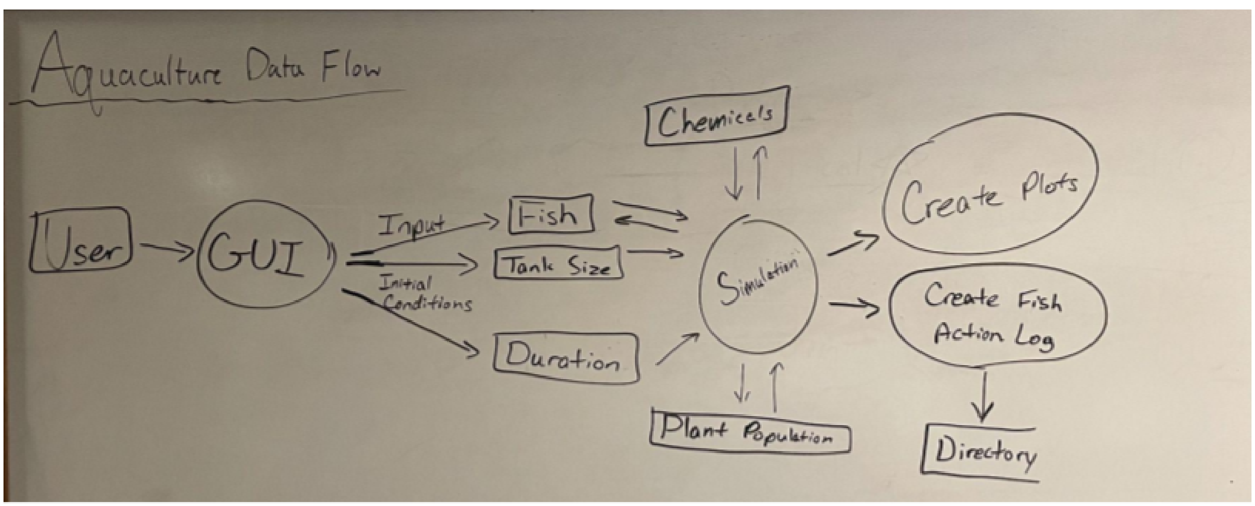

Figure 2: Data Flow Diagram of Simulation

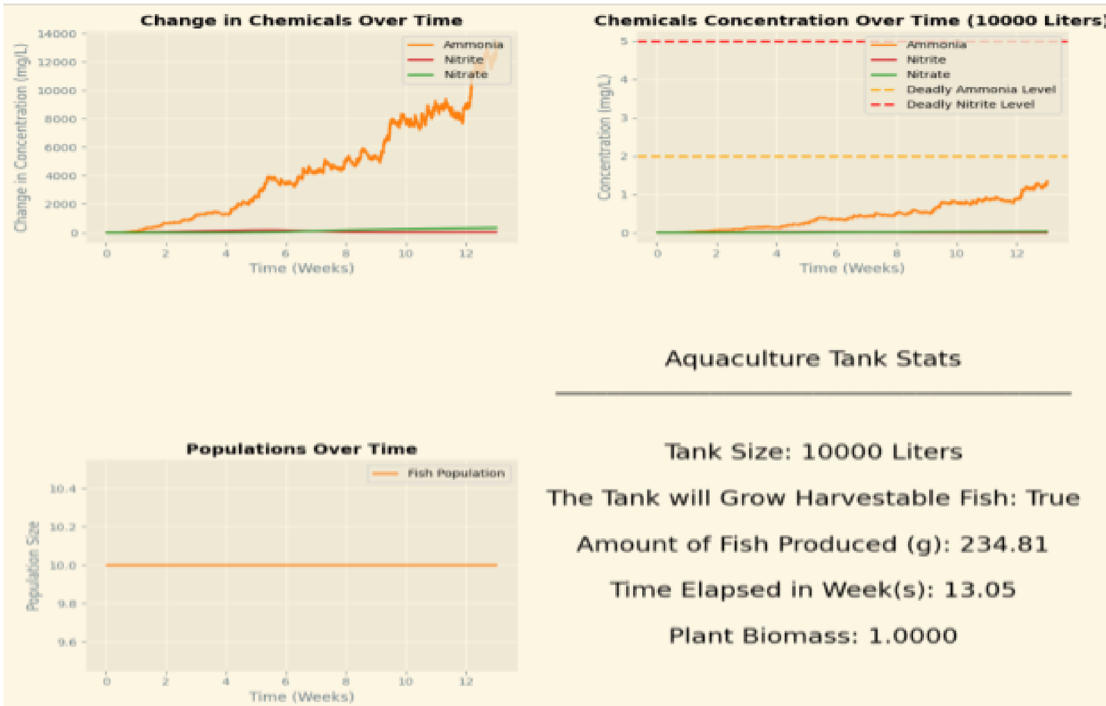

Figure 3: Successful Simulation

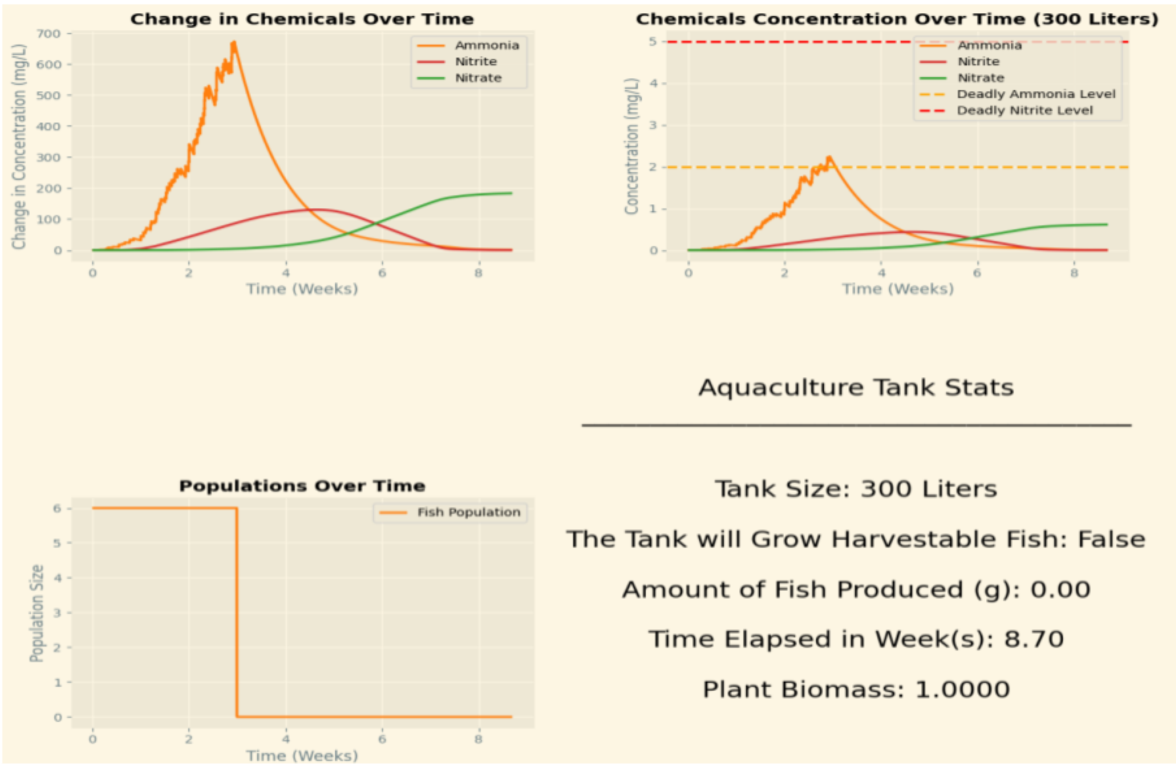

Figure 4: Ammonia reached lethal levels

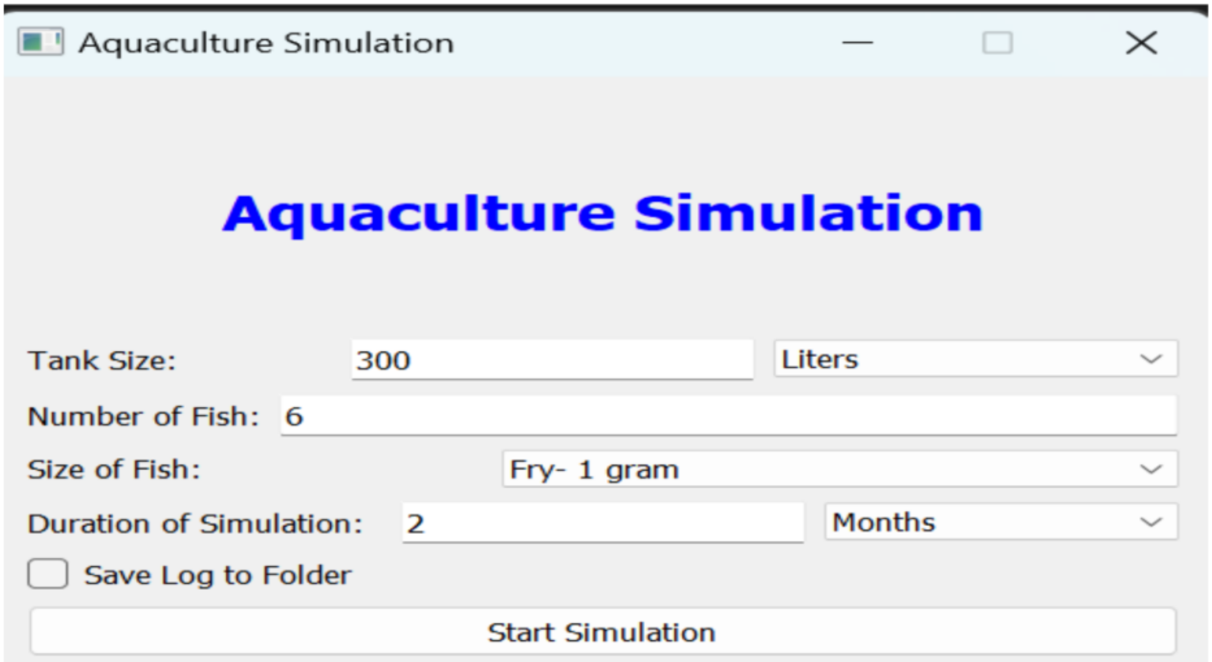
Aquaculture Simulation
Aquaculture Simulation
Tank Size:
300
Liters
Number of Fish:
6
Size of Fish:
Fry- 1 gram
Duration of Simulation:
2
Months
Save Log to Folder
Start Simulation

Figure 5: GUI

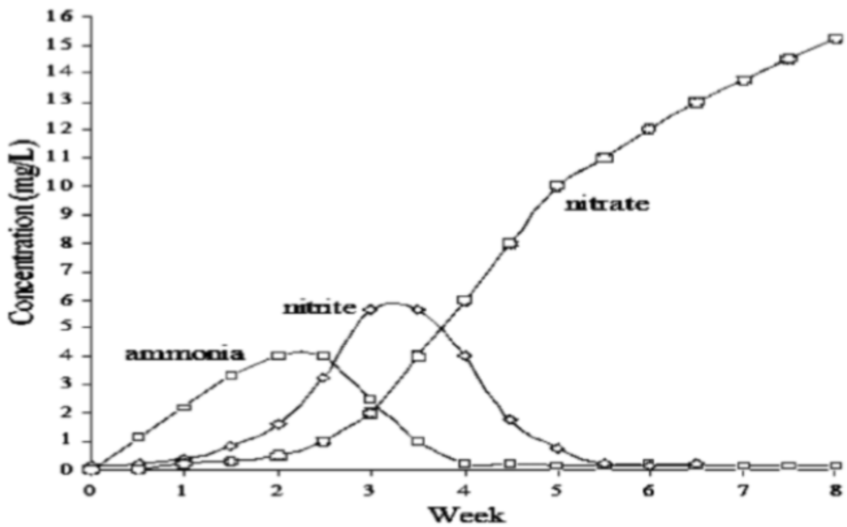

Fig. 6 Aquarium model: normal start-up measures.

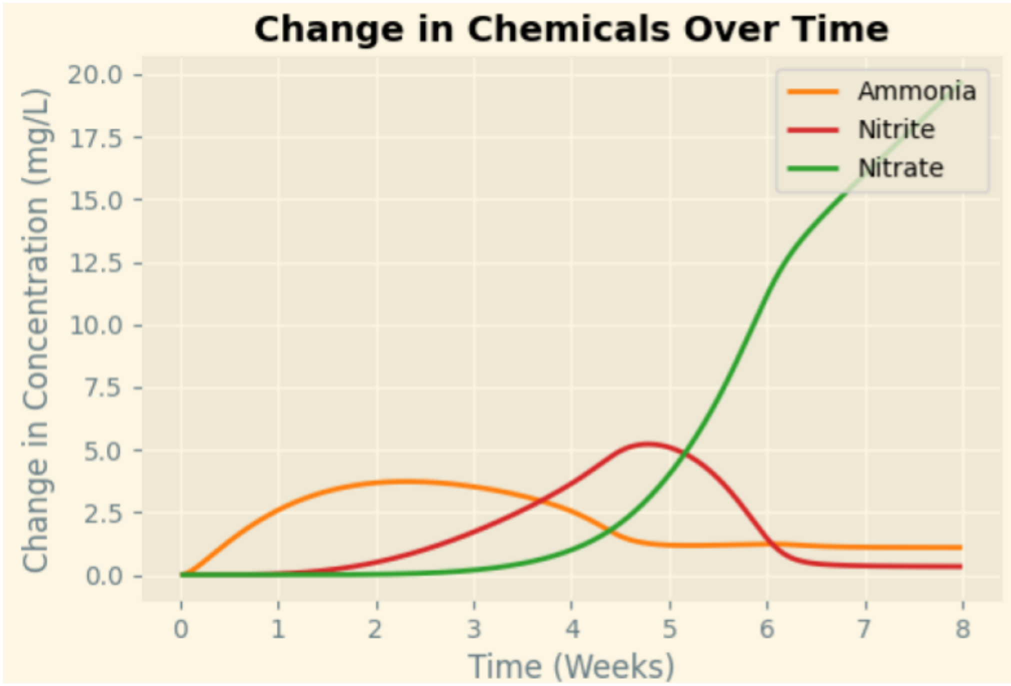

Figure 7: Our Simulation of normal start-up measures

Expansion Ideas:

- Interactive Graphics Application
- Fish reproduction
- Different species of plants and animals included as options within the simulation
- Water type implementation
- More chemical types
- Decades-long simulation potential (using supercomputers like the one in Pittsburgh)
- Investigate Assumptions further

Works Cited

DeLong, Dennis P.; Losordo, Thomas M.; Rokacy, James E.Alavi, S.M.H.; "Tank Culture of Tilapia." *South Regional Aquatic Center*, June 2009, https://fisheries.tamu.edu/files/2013/09/SRAC-Publication-No.-282-Tank-Culture-of-Tilapia.pdf. Accessed Oct. 2023.

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