How much of a rat bounty will effectively curb the food shortage caused by the rat population explosion after the fruiting of the bamboo every 48 years?

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Modeled
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Introduction

Mizoram is a satellite Indian state in Southeast Asia. The people who live there are mainly subsistent rice farmers; they rely on their yearly crop to feed themselves throughout the year. Most years, this lifestyle is difficult yet effective. Local communities come together to help each other produce enough rice to survive.

However, unfailingly, once every 48 years disaster strikes and the equilibrium in this agricultural state is thrown off balance. This occurs with what is locally known as Mautam; the fruiting of the bamboo. The natural clocks of all the bamboo in the region are aligned, and every 48 years they all drop their fruit. Since almost all of Mizoram that isn't cultivated for growing rice is covered with bamboo, this simultaneous fruit production creates millions of tons of bamboo fruit. The fruit is edible to humans, but it is also edible to other creatures, including rats.

There lies the problem. Such an inflated food supply allows the rapid population growth of the black rat. Although other rats experience similar population growths, the gestation period of the black rat is significantly shorter than other rat species, which allows it to grow at a much faster rate than other species. However, the bamboo fruiting creates a false supply, because the mass fruit production will not be maintained in the years to come. Therefore, the food demand of the immense rat population will be too high to allow them to survive. No creature will simply let itself die, so once the bamboo fruit has been consumed, the rats will turn to the human rice crop to survive.

If you are a rat, that is a lovely idea, but if you are a human, perhaps you aren't so happy about it. Every 48 years during Mautam, the people of Mizoram have experienced acute food shortages because of a rat population far above the region's natural carrying capacity.

During the last bamboo flowering, which took place a few years ago, Mizoram officials implemented a rat bounty in an effort curb the rat population growth. For every rat tail collected the government gave 40 paisa (approximately one US cent).

In my model, I will attempt to determine what level of bounty will effectively stop the rat population from growing too large, hopefully preventing a food crisis for the people of Mizoram.

Figure 1: This reference graph shows the behavior of rat population and food supply over time before, during, and after the bamboo fruiting

The Process of Model Building

The first step in the model building process was to construct the Food Supply and Rat Population stocks. This created a basic supply and demand balancing feedback loop. This is essentially what the goal of the model is: to decrease the time it takes for demand to react to supply (because supply is unaffected by demand). I included both the normal rice production of humans and the bamboo fruiting that occurs once every 48 years.

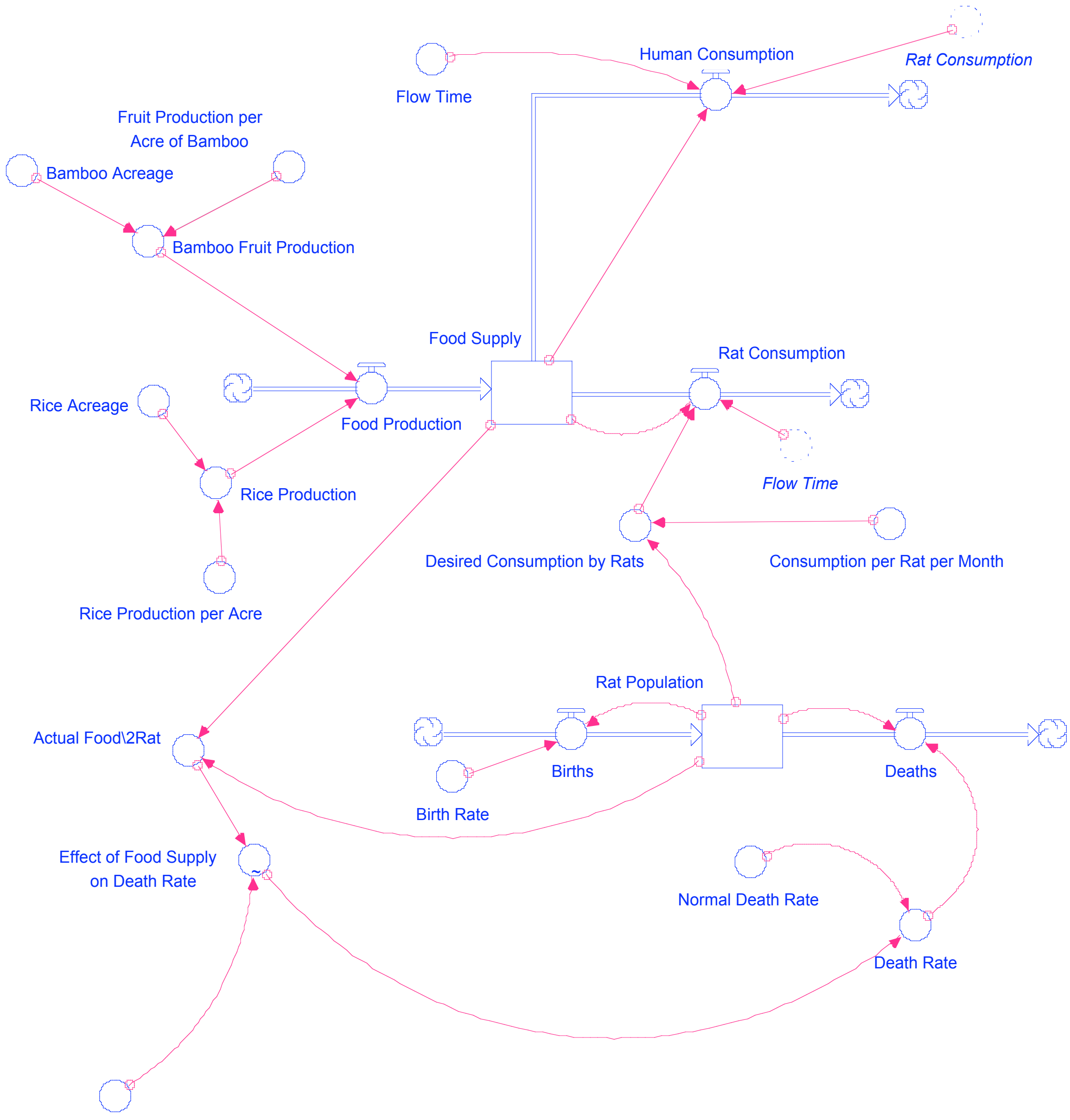

Figure 2: This was the first step of making the model. This models the behavior over time without any intervention from humans.

Next, I needed to add some sort of human policy attempting to ameliorate the food crisis brought on by the rampant rat population. So, I added a rat bounty, and gave it an effect on rat death rate. At this point I used a STEP function to control the rat bounty, which makes the value of the bounty completely independent of the severity of the problem at any given time. This was fixed later in the model by using an information delay and an *Effect of Perception on Rat Bounty* converter.

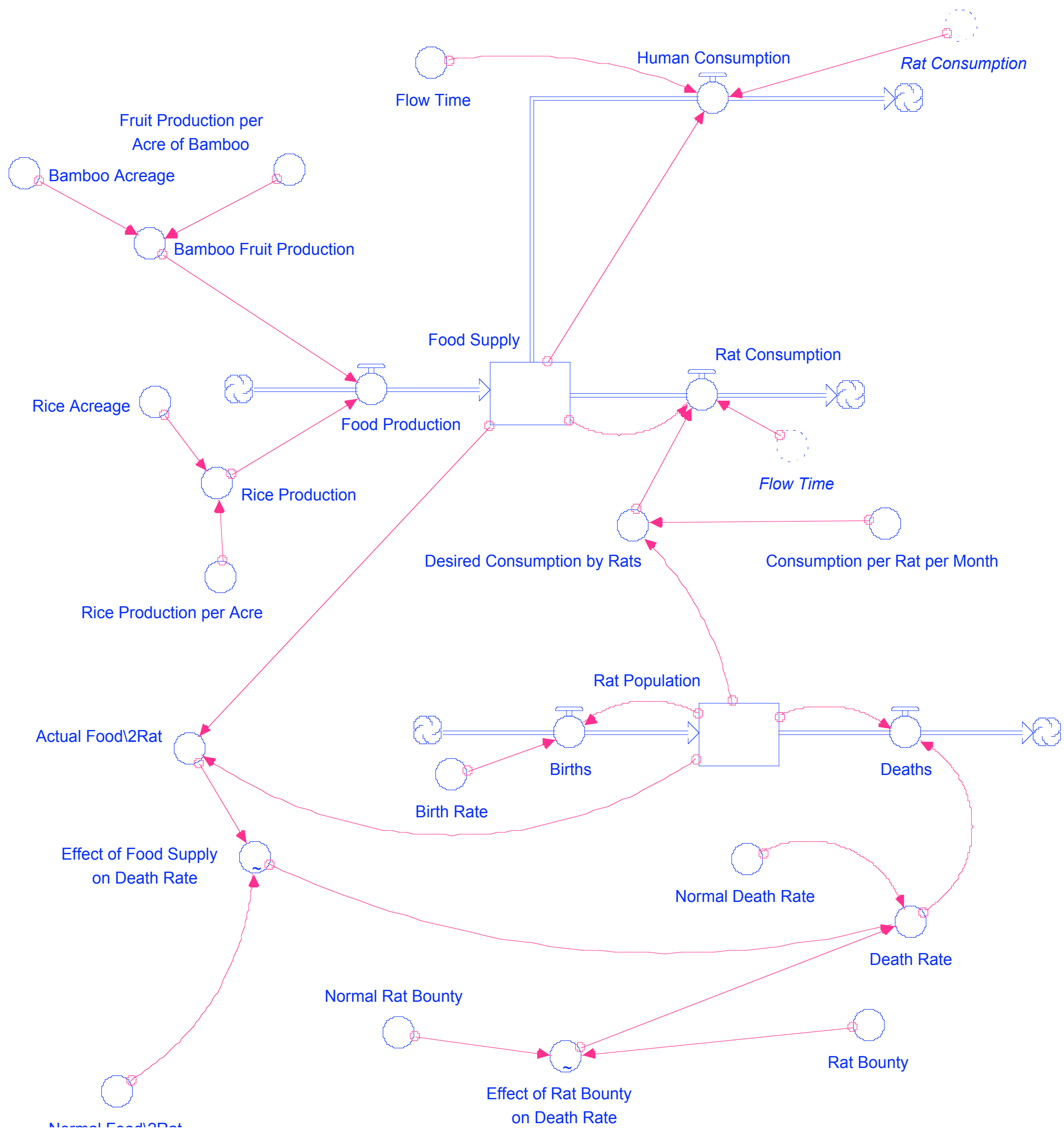

Figure 3: This diagram shows the intermediate step of the model. A human policy (Rat Bounty) had been implemented, affecting the rat death rate, but had yet to be controlled by the food supply and demand behavior that it needed to be.

The Finished Model and How It Works

The model has three stocks, Food Supply, Rat Population, and Perceived Problem. The Food Supply stock has one inflow, which normally solely consists of rice production (rice acreage times the rice production per acre). Since this is a model of the rare bamboo fruiting that happens once every 48 years, the model is set in a year when the fruiting occurs. So, another component of the inflow is bamboo fruit production (bamboo acreage times fruit production per acre). This component uses a PULSE function to model the strange fruiting behavior. This means that once every 48 years, the *Fruit Production per Acre of Bamboo* converter will rise to 20,000 lbs/acre, and then immediately return to zero.

There are two outflows of the Food Supply stock; Human Consumption and Rat Consumption. Although the farmers of Mizoram are largely subsistence farmers, they would sell any surplus they might have obtained. For this reason, I defined Human Consumption as all of the Food Supply minus the Rat Consumption. Since the model only models the behavior for a few years, I assumed that the human population would remain constant, because of the relatively long human gestation period, so I didn't include a stock modeling human population. Relatively long compared to the gestation period of rats that is. The rat gestation period is a matter of weeks, not months, so significant population fluxes can and do occur. For this reason, I went into more detail about the Rat Consumption outflow, defining it as MIN(Desired Consumption by Rats, Food Supply). This means that the Rat Consumption will be the lesser value of the two components Desired Consumption by Rats (Rat Population times Consumption per Rat per Month) and Food Supply. This ensures that the model is more accurate because the rats aren't able to eat more food than there is available.

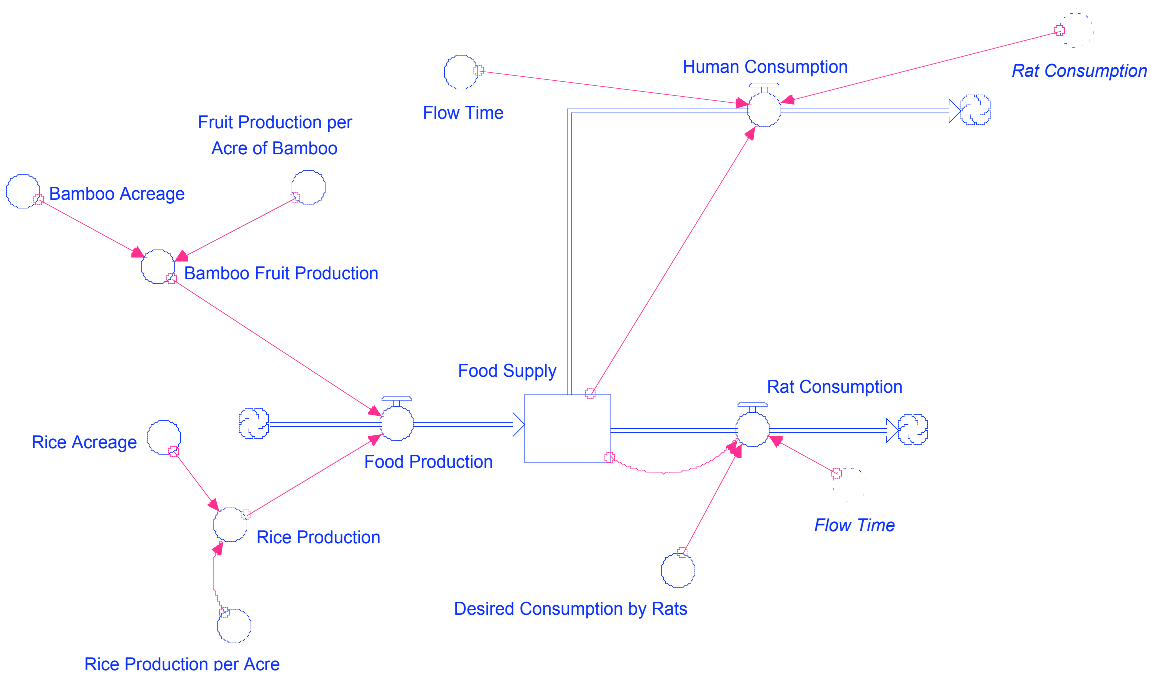

Figure 4: This is the Food Supply stock and its inflow, Food Production, and outflows, Human Consumption and Rat Consumption.

Then there is the Rat Population stock. This stock has one inflow, Births, and one outflow, Deaths. The Birth Rate is set at 100/3 because each female can produce 200 offspring in three months. Since females make up roughly half of the population I divided the birth rate by two to get 100/3. Two things affect the Death Rate: food supply and the rat bounty. The *Effect of Food Supply on Death Rate* is a linearly defined multiplier based on Actual Food Supply divided by Normal Food Supply. The higher the ratio, the lower the death rate. The *Effect of Rat Bounty on Death Rate* multiplier is also linearly defined, and is based on the ratio between the current rat bounty and the normal rat bounty. The higher the ratio, the higher the death rate.

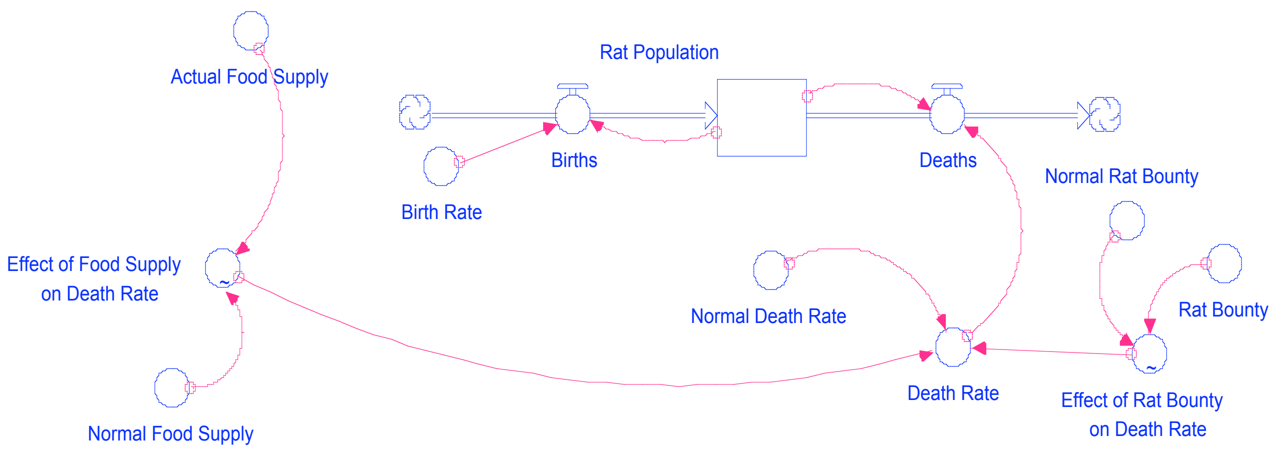

Figure 5: This is the Rat Population stock. The most important parts of this are the two multipliers that affect Death Rate, as they control the growth of the rat population, which is the goal of the model as a whole.

The Rat Bounty is decided based on the Perceived Problem. Although the rat population might be a problem early on, the government won't be willing to spend the money on a rat bounty, and the people won't respond to one without truly believing that the situation is dire. For this reason I implemented an information delay. An information delay models the delay in perception of a problem. The larger the gap between the actual condition and the perceived condition, the faster the perception is changed. In the information delay in my model, I used the food gap between normal human consumption and current human consumption as the actual problem.

The Perceived Problem stock affects the Rat Bounty through the *Effect of Perception on Rat Bounty* Multiplier, which is a logistically defined multiplier. It is defined as such because when the perception is low, they will be less worried about the problem, and not offer as high of a bounty per rat. When they perception of the problem is extremely high and the bounty is already extremely high the government will at some point believe that the rat bounty approach is futile and will stop increasing the bounty. This multiplier changes the rate at which the Rat Bounty changes. The *When to Turn on Bounty* converter sets a level of Perceived Problem that must be attained before the government will see it necessary to act and implement a bounty. The multiplier then determines by what increments the Rat Bounty will increase by each month.

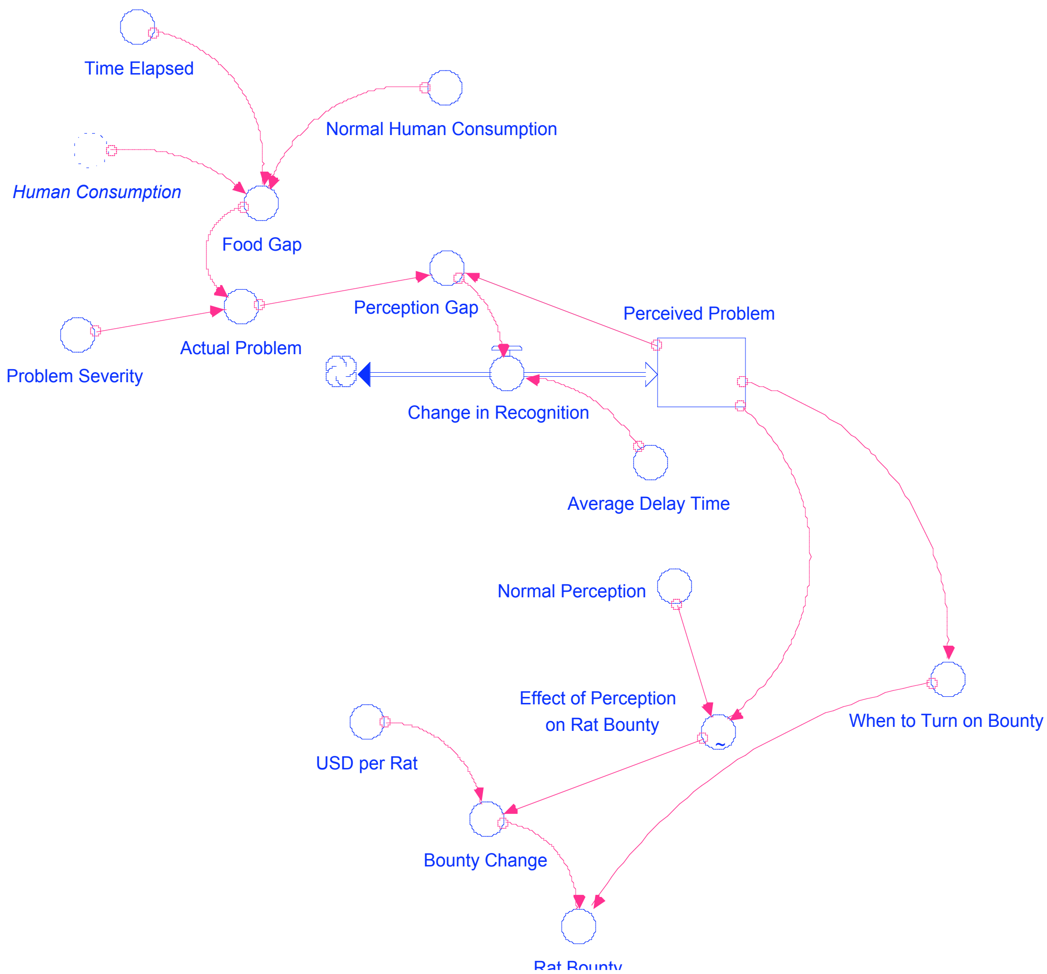

Figure 6: This is the information delay and bounty implementation part of the loop. It deals with human involvement in the model.

The Model Feedback & Loop Story

The Model Boundaries

To keep my model manageable, I had to leave out some aspects of the system that are somewhat important. I didn't include the human population because I felt that its change over the time period I was modeling (less than three years) would be insignificant. I didn't include any natural rat food sources other than the bamboo because finding data on things such as seeds and nuts and whatever else rats eat proved to be impossible, and making an educated guess would just hurt the model behavior. I didn't include natural predators of the rat in the model. I figured that their population would simply follow the behavior of the rat population with a slight delay, and also couldn't find very good data on snakes. The simplification that was most difficult for me to make was the clumping together of all food sources into one food supply. In the real world, rats would eat a different percentage of each type of food than humans to make up their total consumption. Therefore, shortages in different food supplies would affect the two species differently. For example, a rice shortage is much more devastating for the human population than for the rat population. However, figuring out the percentages that rats eat of rice and of other foods is not possible without doing field research, and even then is quite difficult.

When deciding on time specs I was faced with two options: months or years. Initially, I was leaning towards years because the bamboo fruiting happens once every 48 years. Then I realized that if I used years each population explosion and food shortage would be almost indistinguishable on a graph of hundreds of years. For this reason I chose to use months, and to simple explore the behavior surrounding one occurrence of Mautam instead of multiple. So, I started the model six months before the bamboo fruiting, and continued until about two years afterwards in order to see the system return mostly to equilibrium.

Model Testing

To make sure that the model was behaving correctly, I made sure that everything was at equilibrium before the fruiting. All of the multipliers are at one and all of the stocks are constant. Then I implemented the bamboo fruiting. I knew that all of the loops were balancing, so everything should go back to equilibrium after the event.

The model does agree with my reference behavior over time graph. The rat population explodes a few months after the fruiting, and then starts to become smaller as all of the food is consumed.

In my sensitivity analysis I was trying to find how reactive the government would have to be in order to curb the rat population and prevent the food shortage. To do so, I altered the rate at which the government increases the bounty each month. There is an *Effect of Perceived Problem on Rat Bounty* multiplier that alters the rate of change of the bounty based on how convinced people are that there is a problem. In my sensitivity analysis I basically altered the amplitude of that multiplier. For example, if at a certain level of perception the rate of bounty increase was one cent a month, the six sensitivity analysis graphs would produce rates of increase of one cent, two cents, three cents, four cents, five cents, and six cents respectively.

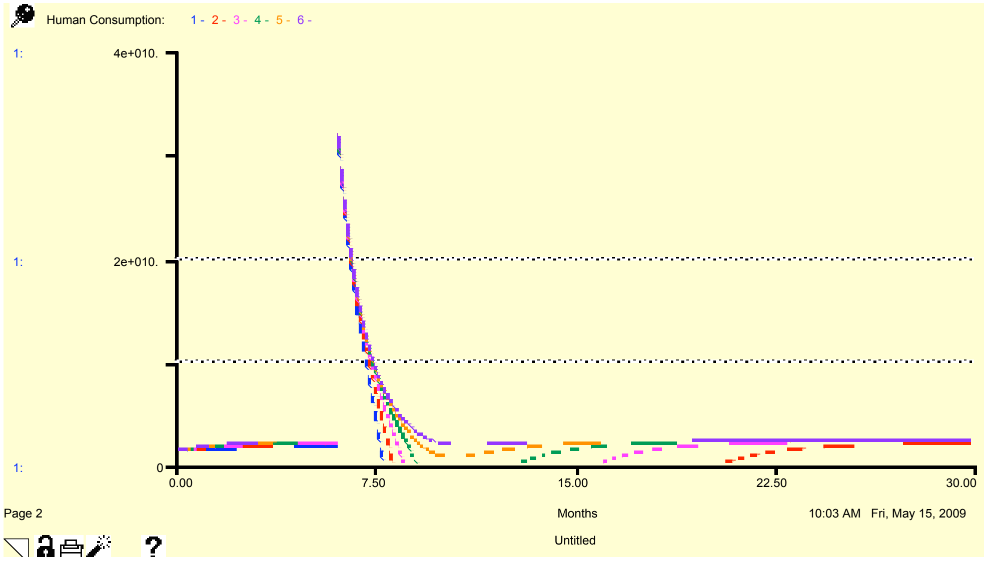

Figure 10: This is a sensitivity analysis graph of human consumption. The parameter I altered was the amplitude of the *Effect of Perception on Rat Bounty* multiplier.

The Results of Modeling and Thinking

According to our graphs and tables, the people of Mizoram will experience a severe food shortage unless governmental action is taken. Based on the sensitivity analysis I did, the amplitude of the rate of change of the bounty would need to be five times as high as the government adopted the last time Mautam happened in order to prevent total devastation, and six times as high to prevent any negative effects on the food supply.

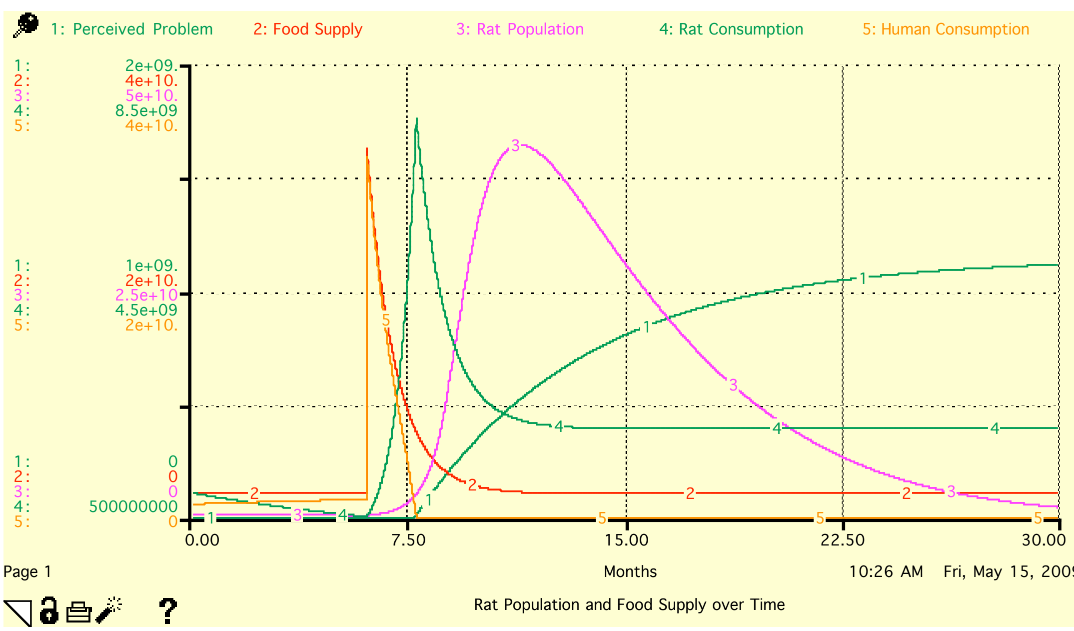

Figure 11: This is the graph of the system with the amplitude of the bounty rate of change at one. Notice how the human consumption goes to and stays at zero for an extended period of time.

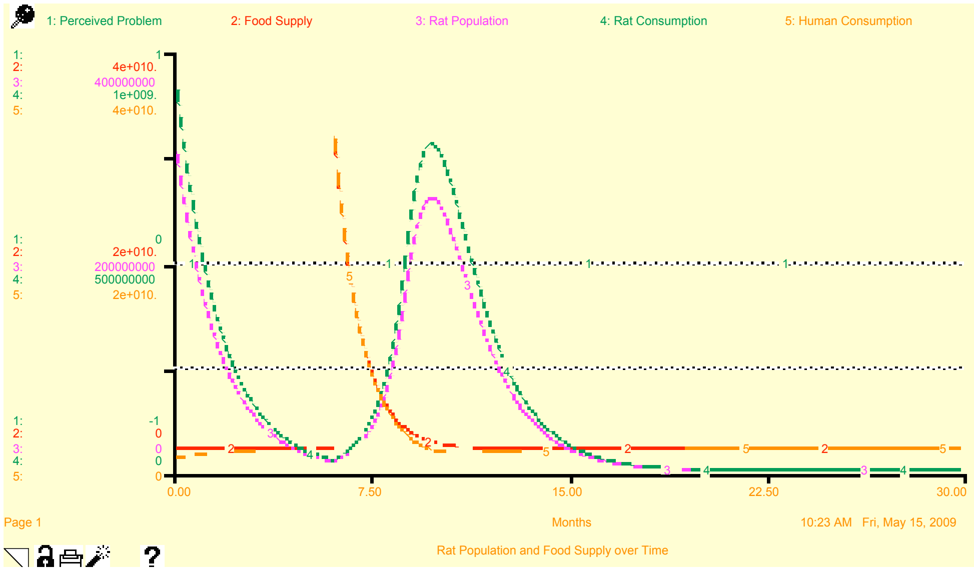

Figure 12: This is the graph of the system with the amplitude of the bounty rate of change at six. Notice how the human consumption never goes below its normal level.

The Key Learning from the Modeling Process

- Without governmental action or some type of human intervention, a significant portion of the people of Mizoram will starve following Mautam
- In order to curb the rat population to prevent food shortage using a bounty system, the government would need to implement a system in which they are willing to increase the bounty at a rate six times what they have in the past
- Attempting to stop Mautam from occurring so dramatically by decreasing the bamboo acreage in Mizoram is not plausible because the acreage required to do so is one-fifteenth of the current value. Such a violent change in the ecosystem would undoubtedly cause more problems than it would solve.
- To test other forms of human intervention (i.e. planting crops that are less appetizing to rats such as ginger) I would simply put another converter coming off of Perceived Problem and then link it to Death Rate (or in the case of my crop-change example to Food Production) through a multiplier

From building this model, I learned about the difficulties that governments face in choosing the correct policy. Also, I learned how using models of real world systems can facilitate the collection of accurate data. For example, before running my second sensitivity analysis altering Bamboo Acreage, I thought that I had found an effective, although controversial, solution. However, upon running the sensitivity analysis, I could easily see that my solution was not feasible. In other classes, I am often asked to posit logical solutions to problems or am given the solutions reached by other people. Using STELLA and models of complex systems I can test out my own theories and confirm those of others instead of faithfully accepting them as fact. Where other classes ask me to memorize, this one dares me to explore.

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