Model Design Review

(1) What part of your phenomenon would you like to build a model of?

I would like to model spatial interaction of 2 fish and 3 prey types in an estuary, featuring different habitats, simple prey population dynamics, reproduction and competition. The model will have simplified bioenergetics governing the state of each agent.

(2) What are the principal types of agents involved in this phenomenon? Illustrate all of the agent types necessary for the model.

The only moving agents will be two fish breeds acting as competing predators. Three prey types will be mostly fixed to a patch, varying only in their population densities. These are worms, bivalves and zooplankton.

Fish eggs and prey larvae can be seen as passive agents, since they simply track larval transport from the spawning location to larval settlement patches.

(3) What properties do these agents have (describe by agent type)? Describe for all agent types.

Both fish breeds have similar properties. Both breeds will have some fixed parameters that can be globally set by the observer:

- age-at-maturity: age at which a fish becomes an adult and is fit for reproduction
- max age: maximum age
- maximum feeding rate: maximum total size of prey a fish can eat in a day
- assimilation rate: percentage of energy retrieved from digested prey (the rest is eliminated from the body)
- energy reserve size: the size of the energy reserve, measured in arbitrary energy units, which limits feeding rates
- maintenance cost: energy required to support life
- small-movement cost: energy cost of staying in the same patch
- large-movement cost: energy cost of moving to another patch
- reproduction threshold: surplus energy level at which an adult fish alters its psychological state to “reproduce”
- cost-per-gamete: energy cost of producing one gamete, which is split in half between male and female. This is used to calculate the number of eggs to generate.
- Days until hatch: days until eggs become larvae
- Egg mortality: fraction of eggs that never make it to larvae

Fish state variables include:

- coordinates of their current patch
- sex
- an energy reserve compartment that stores energy assimilated from consumed prey, minus the maintenance costs
- age (days)

- eating: what prey will the fish be eating on the next time step?
- life stage: juvenile or adult
- a current psychological state, or desire, that drives decision-making in the movement model. If energy reserves are low, feeding is the main goal, whereas a male seeking to reproduce but without any females around will decide to move, if there is enough energy to pay the large-movement cost.

All three prey types will have similar fixed properties, but they can be different between types:

- prey size: this impacts feeding rate, because larger prey occupy more volume in a stomach.
- energy value: this is the amount of energy contained in 1 prey item, minus the energy required to eat it (chase, chew, filter…).
- Carrying capacity in mudflats: maximum number of prey in mudflats
- Carrying capacity in canals: maximum number of prey of this type in canals
- reproductive potential: maximum number of larvae produced per prey individual in a day
- days-between-hatches: number of days to wait between larvae emissions
- reproduction radius: radius where larvae may settle and become “adult” prey, this can be set to 0 to mean “all patches”

Prey will be represented as patch variables, one for each population density and one for each prey property, so all prey in a patch have the same properties. When a patch produces larvae, a timer starts counting the days from last hatch.

Prey larvae and fish eggs may be considered agents, but they are merely numbers on a patch that keep track of how many juveniles to grow. Larvae for each prey type will be immediately spread across the defined radius, instead of simply increasing the population on the same patch. The number of eggs produced by fish will be listed in a patch variable as well, and the list length will be equal to the “days until hatch” parameter, so the list can move each day and the number removed is the number of new juveniles to place.

(4) What actions (or behaviors) can these agents take (describe by agent type)? Describe all appropriate behaviors for all agent types.

Fish will move by examining surrounding patches and deciding to stay or move to another patch based on the competition existing on the current patch, potential energy gains, current energy levels and their psychological state. While on a patch, they will eat prey based on the energy requirements and feeding rate. Because fish can only pick one prey type per day, prey choice will involve a decision process based on the potential energy gains. They can also reproduce if a fish of the opposite sex with enough energy to do so is present. Surviving fish eggs will remain in the patch of origin for the required time. Once they hatch, juveniles will be randomly distributed across mudflat patches (less water flow, more protection) across the map. If they can pay maintenance costs given the current competition in the patch, they will be added as fish agents, if not the settlement is not successful and larvae are assumed dead.

Prey will reproduce in a pre-defined frequency. Larvae will spread across a radius and become new prey adults, within the carrying capacity of each patch.

(5) In what kind of environment do these agents operate? Describe the basic environment type (e.g., spatial, network, featurespace, etc.) and fully describe the environment.

The environment will be a spatially explicit depiction of a generic estuary with patches representing 2 habitats, mudflats and sandy canals. The canals will be randomly generated based on a pre-defined percent cover, by “carving” canal patches with the help of a turtle moving across the map. Patches will ideally represent 1 square meter. Each habitat will better support different types of prey. Worms prefer mudflats, bivalves prefer the canals and free-swimming plankton will have no preference. Depth and water currents will be ignored.

(6) If you had to “discretize” the phenomenon into time steps, what events and in what order would occur during any one time step? Fully describe everything that happens during a time step.

The events could be discretized ideally into a day, but longer periods are possible if computation time becomes a problem. Increasing the time scale would probably mean increasing the spatial scale, because the model assumes every fish can only sense their current patch in every time step. Because NetLogo orders turtles randomly, both fish species would have to be included in an agentset so that none is picked systematically first to move and eat.

A time step would look like this:

- Prey reproduce and new prey are added to neighbouring patches
- Fish set their psychological state based on low energy reserves (feed) or high reproductive energy (reproduce).
- Fish make the decision whether to move or stay based on competition and available resources, as well as the current psychological state. Energy is spent accordingly.
- Fish decide what prey to eat on the new (or same) patch, based on what other fish have decided (competition for each prey). If a fish has still not picked the new prey, other fish assume they will maintain the same prey as in the previous step.
- Fish feed on the selected prey type and prey numbers are depleted.
- Fish pay maintenance costs and energy budgets are calculated. Fish that fail to pay maintenance die.
- Adult fish with enough energy left to reproduce look for an agent of the opposite sex in the patch. If one is found, the amount of gametes produced by each one is calculated (total energy available divided by energy per gamete) and the minimum of the two fish (since one of each is needed), minus egg mortality, is taken as the number of eggs spawned.
- Update fish age. If it equals max age, die.
- Fish eggs in patches that reach the hatching age hatch and are distributed across mudflats.
- Calculate the number of new fish that can be placed on a patch based on the ability to pay maintenance costs given the available resources and competition.

(6) What are the inputs to the model? Identify all relevant inputs.

The initial number of fish from each breed, the percentage cover of each habitat type and all the parameters described for fish and prey.

(7) What do you hope to observe from this model? Identify all relevant outputs.

I hope to observe, in a very simplistic way, if two competing predators can find a way to occupy different niches to survive and avoid the heavy costs of competition, even if the preferences for a certain habitat or prey are not specifically stated.