**Dead Zone Game Instructions**

*\*This game has been modified from Kastler (2009). See ‘additional resources’ for the original paper*

**Introduction:**

Students in the classroom will be one of four players in an aquatic ecosystem: Nutrients, Phytoplankton, Oxygen (O2) and Carbon Dioxide (CO2). During the course of the game, nutrients can become phytoplankton and vice versa (through reproduction and decomposition respectively) and oxygen can become carbon dioxide and vice versa (through respiration and photosynthesis respectively).

Students will wear name tags that are interchangeable between either oxygen/carbon dioxide or phytoplankton/nutrients and will flip over name tags during the simulation according to their roles. The simulations will use different starting numbers of each of these four components to simulate what happens to an ecosystem with limited nutrients, a pycnocline, and with both a pycnocline and excess nutrients.

The simulation is played around a large enough area that students can move around in. Designate one end of the room the air-water interface and the other end the sediment-water interface. One side will be the Mississippi River discharge where nutrients come out. The ecosystem ‘wins’ if there is enough oxygen left at the end of the round.

**Processes:**

Near the air-water interface, a phytoplankton player can combine with a CO2 and a nutrient (these three players briefly link arms) to create O2 and more phytoplankton. The nutrient player switches his/her card to the phytoplankton side and the CO2 player switches his/her card to O2 side. This simulates CO2 being converted to O2 through photosynthesis and the phytoplankton reproducing using the nutrients.

If a phytoplankton has walked across the air-water interface (up and back) three times without finding a nutrient, they will die and sink to the bottom of the water body. **Note: dead phytoplankton are heavy enough to pass through the pycnocline but oxygen and carbon dioxide are not**. Once phytoplankton reach the bottom (the water-sediment interface), they link arms with an oxygen. The phytoplankton player flips their card over to the nutrient side, and the oxygen player flips their card over to the carbon dioxide side. This simulates the process of decomposition where bacteria break down dead phytoplankton using energy from respiration. **Nutrients may not pass the pycnocline**.

**Round 1- healthy ecosystem:**

In this round, there will be no pycnocline and no excess nutrients. For this round, there must be at least one more O2 player than the sum of the phytoplankton and nutrient players combined. (In a 20 student class there would be two phytoplankton, two nutrients, eight oxygen, and eight carbon dioxide). Hand out role cards in proportion to your class size. Line up the nutrients at the Mississippi River discharge and have them come out one by one when the simulation begins. All other players can mix freely throughout the playing area since there is no pycnocline. After several minutes of play, count the number of each player type and discuss what (if any) changes have occurred to the ecosystem.

**Round 2- healthy ecosystem, pycnocline:**

Have students revert back to their original roles (the same numbers of each player in round 1) only start all of the CO2 players above the pycnocline and all of the O2 players below the pycnocline (this is for simplicity). Explain that surface water will have plentiful oxygen that diffuse through the air-water interface so we are only concerned about oxygen levels in deeper water. Again, line up nutrient players at one end and have them come out one by one. Play will end once there are no more nutrients at the air-water interface. Discuss starting and ending levels of O2 and CO2.

**Round 3- excess nutrients, pycnocline:**

 In this simulation the sum of phytoplankton and nutrients will be greater than the oxygen. (In a 20 student class, there would be two phytoplankton, six nutrients, six O2 and six CO2). It may be easiest to have most students stay in their starting roles, but ask one O2 and one CO2 to switch to a nutrient. Before beginning the round, discuss the reasons why there may be more nutrients in a watershed. Again, start the O2 players below the pycnocline and the CO2 players above the pycnocline. Line up the nutrients and have them come out one by one. Allow the class to proceed with the simulation. At first the number of phytoplankton will peak (i.e. an algae bloom) however when nutrients are depleted, phytoplankton will die, sink to the bottom and be decomposed; depleting oxygen levels at the bottom.

**Round 4- Addition of animals (optional):**

If desired, additional player types can be added to the simulation. A fish/nutrient and worm/nutrient player can be added to the system. The fish may walk anywhere it likes (can cross pycnocline) and every 30 seconds (or two lengths of the water body) must find one O2. This O2 would then become a CO2 and the fish keeps swimming. If the fish cannot find an O2 it dies and sinks to the bottom to decompose. A worm stands in place while raising his/her right arm, lowering it, then raising his/her left arm and lowering it. If an O2 is not found by the time he/she has raised his/her arm five times, it dies and will become decomposed. Decomposition by the worm or fish is the same as with phytoplankton- they link arms with an O2, and become a nutrient.

 Instead of playing the round, you can discuss with the class what happens to other organisms in the ecosystem in a hypoxic system. Do they die? Do they leave the area?