# Results

Fig. 1 – with two subplots showing only trajectories of two cases.

As the old model shows that biofouling is basically controlled by the total density of the particle, the new model reflects the same principle. (PLOT? – this phenomenon is shown in the density oscillation plot.) When the density of particle exceeds sea water density the particle sinks and when the density is below sea water density the particle moves up. Bounce point is defined here as the minima in the trajectory curve, which is always found where the density of particle equals the sea water density.

In our new model, by adding dead-cell behavior, the frequency of particle trajectory is found smaller than in the old model. Besides this, the trajectory is also found to be more regularly behaved. (The amplitude of the trajectory is bigger, but only slightly.)

Fig. 2 – contribution diagram for living=coll+growth-(dead), dead=resp+mort-diss, negative terms on negative side

But what is causing these differences? From the model settings we know that the respired and mortality of the attached living cells do not disappear along with the cell mass. Instead, they transform into attached dead cells and take part of the cell mass with them. So, with time changing the attached dead cell mass accumulates and reach an equilibrium under the frustule dissolution process. In our settings of the model, the dead-cell mass contributes to 12.5% of the total algal mass. And this dead-cell mass is relatively steady, acting like part of the plastic itself and adding more mass to the initial clean plastic. (PLOT? – showing dead-cell mass is relatively stable) Dead-cell behavior is definitely important in the different trajectories and the dissolution rate is one of the keys to control the attached-dead mass at equilibrium.

Fig. 3 – contribution diagram for varied diss rate, mainly to show the fraction of dead mass

In order to find out how the dead-cell behavior affects the different trajectories, sensitivity analysis is run for 10 simulations with different dissolution rate varying from 0 to 1. When the dead-cell mass is relatively big, the pattern of which are not characteristically different, which means the frequency, amplitude are quite similar (PLOT? – like fig. 1 but showing with [2.5e-3, 2.5e-2, 2.5e-1. And this conclusion is valid only when the plot shows so, otherwise just say that they are similar.] The trajectory itself is still different and chaotic due to deterministic chaos, with definition that aperiodic long-term behavior in a deterministic system that exhibits sensitive dependence on initial conditions)

When the dissolution rate is relatively big, meaning quite much of the dead-cell mass is dissolved into the water and even no dead-cell mass is remained. Then it will become exactly the same case as shown in the old model (PLOT? – old=new\_diss1.0). Since this project focuses on the influence of dead cells, the discussion will then focus on a range where dead is significant from [0 – 2.5e-4].

Fig. 4 – trajectories of different diss-rate cases [0 – 2.5e-4]

Decreasing frequency of the trajectories are found with decreasing dissolution rate. This is because the pattern of the trajectory is very sensitive to the equilibrium level of attached living cells. Fig. 3 shows that decreasing dissolution rate leads to increasing attached dead and decreasing attached living. As growth, respiration and mortality terms are all exponentially related to the mass of attached living itself, the less attached living cells are the slower the mass change is, thus smaller the frequency of oscillation is.

Increasing amplitude of the trajectories are found with decreasing dissolution rate. The higher density of the particle resulted from higher dead-cell fraction makes the particle more sensitive to mass change. Specifically, when a much denser particle encounters a minor growth in mass will lead to sinking. Because the sinking happens so early that the algae does not have enough time to accumulate. The growth on a heavy particle stops at a much lower level at EZD as on a lighter particle does. Little attached living mass leads to even little death rate. As a result, particle below EZD takes much longer time to recover the density, thus leading to longer sinking time. Eventually, the denser particle reaches a deeper sinking depth.

Sinking depth

As dissolution rate determines the sinking depth by controlling the total particle density via dead-cell mass, the density of frustule itself is also important to sinking depth. The denser the frustule is the deeper the sinking depth is.

Dead-cell behavior and equilibrium

When dissolution rate is not enough to take out the instant leftover, the dead cells will accumulate. The dead cells can not build up unlimitedly, because the density of the particle will increase accordingly. When the denser particle reach a certain depth where there is barely growth and collision takes place, only respiration and mortality present. The respiration and mortality beat the dissolution term and consume the attached living cells until there is none. Eventually, there is no input to the dead cells as well and dissolution continues reducing the particle density until the particle is light enough to float and gain new living cells again. However, the loop will eventually lead to equilibrium.