Do not worry about the horizontal grid cell resolution: assume that we are "somewhere" in the sea, with given light (you can use the time series provided previously, let Ole Jacob know if they are missing).

Consider only one vertical rope. Allow the rope to be divided into M segments of fixed length x. For $i = 1\ldots M$, let z_i denote the depth of the top of each depth layer i from the water surface such that $z_i = (i\text{-}1)x$.

Assume N super-individuals on each segment (in each depth layer (i)). Each super-individual on the i^{th} segment will represent n sub-individuals with *exactly* the same state values (*e.g.*, they will be treated in exactly the same way - given the same environmental data, including shading - in the model). Note that the total number of sub-individuals each super-individual represents can be different (*i.e.*, n is not necessarily constant across super-individuals on each segment or the same for similar super-individuals on different segments). Thus, for $j= 1\ldots N$, the total number of sub-individuals on the i^{th} segment ($n_{i,tot}$) can be expressed as:

$$n_{i,\,tot}=\sum_{j=1}^{N} n_{i,\,j}$$

For the purpose of this exercise, the only state variable that we will consider is the frond size A (all other state variables held constant). For the i^{th} segment and for $j= 1\ldots N$, let frond size of each of the N super-individuals be denoted as $A_{i,j}$.

For simplification, assume that all sub-individuals represented by each super-individual on the i^{th} segment are spread out evenly (Figs. 1, 2). Also assume that the plants are evenly spread out in all directions from the rope (initial simplifying assumption). Later, we can consider different or more complex assumptions.

Assume a background attenuation of k_{bg} = 0.18 (which includes all other causes for light shading in the water, including the water itself, silts, cDOM, *etc.*), or you can use the one from the light data. The total attenuation (k_{total}) will be:

$$k_{total} = k_{kelp} + k_{bg}.$$

Where k_{kelp} is the attenuation due to shading.

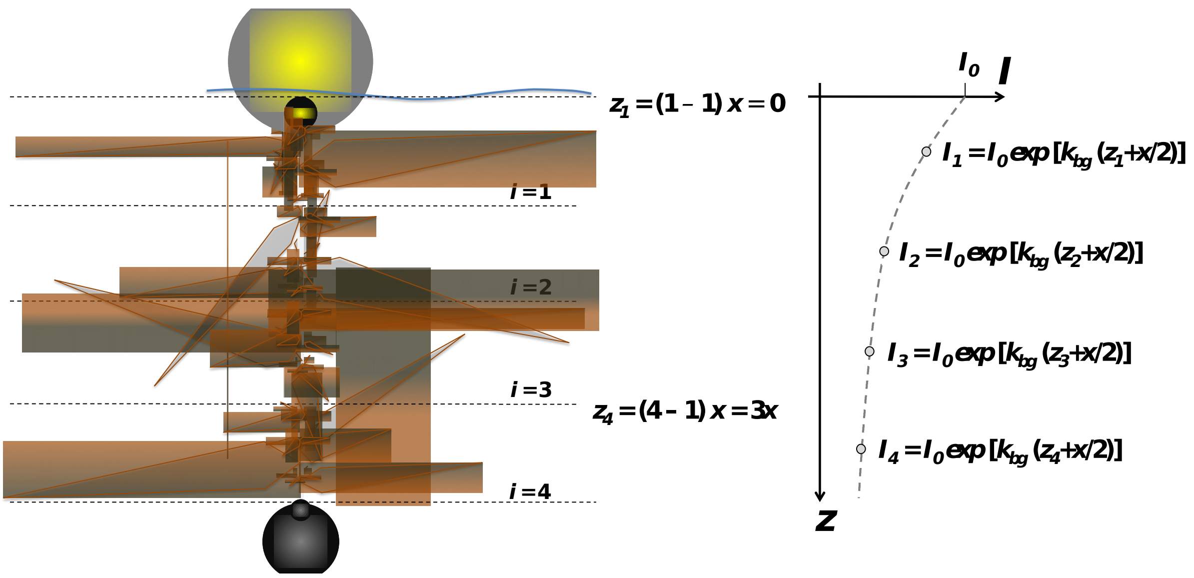

Figure 1. Vertically deployed kelp line.

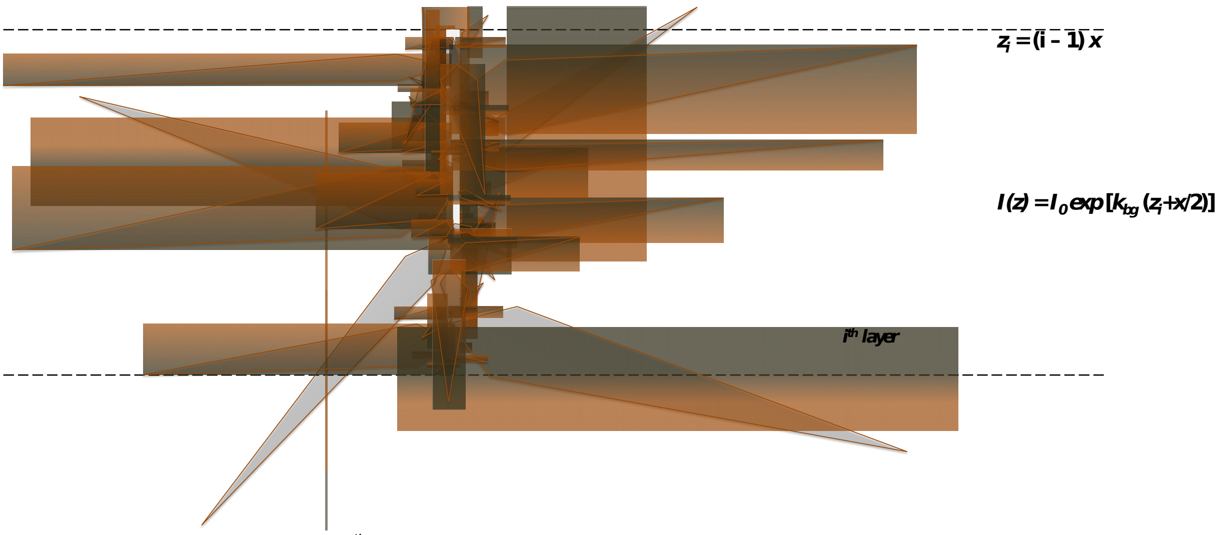

Figure 2. Kelp blades on the i^{th} section of rope.

Calculation of light levels:

Assume the light intensity (photosynthetically active radiation, PAR) just below the surface is I_0. We calculate the light intensity for the middle of each depth layer (i). Assume all sub- and super-individuals in the same depth layer will experience the same *background light.* The actual light received must be adjusted by the presence of kelp fronds (shading), the degree of which will depend on the size of each super individual. The light available for the kelp plants in the i^{th} segment, without considering self-shading by the plants is:

$$I_i = I_0\ exp[k_{bg}\,(z_i + x/2)]$$

The tricky part is that we need to calculate different light received for the different super-individuals; small plants will be relatively more shaded by bigger plants. Let $k_{i,j}$ be the extra attenuation of light for super individual number j due to shading by all the super individuals, including shading by the members of super individual number j itself, in layer i. Then we calculate the light available for super individual number j as:

$$I_{i,j} = I_0\ exp[(k_{bg} + k_{i,j})(z_i + x/2)].$$

Initially, lets disregard the effect that kelp growing on the (i-1) segment may have on the kelp growing on the i^{th} segment (or any other segment). Rather, consider first only the local effects of kelp growing on the i^{th} segment on themselves in addition to the background light shading by plankton etc.

Some realistic data are provided in Table 1 to support initial work, assuming that we can model the system using three super-individuals (and associated sub-individuals) growing on the i^{th} segment.

Assume the fraction of PAR absorbed by the kelp fronds (➔$_{kelp}$) is 0.7 (70% of light is retained by the frond – not necessarily for photoynthesis, but simply absorbed by the tissue).

Table 1. Data regarding areas of each super-individual classification and number of sub-individuals per super-individual

Time	A_{1i} (cm^2)	n_{1i}	A_{2i} (cm^2)	n_{2i}	A_{3i} (cm^2)	n_{3i}
April	20	100	40	100	60	100
June	200	25	300	25	1200	25