Appendix to "The Potential for Upscaling Kelp (*Saccharina latissima*) Cultivation in Salmon-Driven Integrated Multi-trophic Aquaculture (IMTA)" (**DOI: 10.3389/fmars.2018.00418)**

**Modelling differentiation between uptake of NO3- and NH4+** **in *S. latissima*:** The *S. latissima* growth model (Broch and Slagstad (2012); Broch et al. (2013)) was updated so that NO3- and NH4+ (representing NH3+ and NH4+) are taken up separately and simultaneously at equal maximal rates, neither compound inhibiting the uptake of the other (Ahn et al., 1998). It is assumed that NH4+ is given priority over NO3- *for growth* based on observations that the presence of NH4+ decreases the rate of reduction of NO3- into NH4+ in *Laminariales* (Young et al., 2007). NO3- will still be taken up in the presence of NH4+, but a smaller part of the internal NO3- reserves are spent for growth.

Next, we present the details of the model for simultaneous uptake and utilization of NO3- and NH4+. The parameters, variables and notation used in the following are described in Table A1.

Let  denote the external (water) concentration of compound *X.* The uptake rate for NO3- is calculated as

# .

# It is assumed that NH4+ is taken up only as required and available externally, and not stored. The *potential* uptake of NH4+ is given by:

,

sustaining a *theoretical* instantaneous frond area increase of:

.

The *actual* instantaneous area specific growth rate, *µ*, may increase beyond the potential from internal reserves if [NH4+] is high enough:

**;**

(Broch and Slagstad, 2012). The actual uptake rate for NH4+ is then determined by:

.

The equation for the internal NO3- pool is then:

.

The use of NH4+ rather than NO3- for growth saves the equivalent of 288 kJ (mol NO3- reduced)-1 (Falkowski and Raven, 2007) of the carbon reserves, assuming a free energy content of the carbon reserves of 2880 kJ mol-1 (glucose).

The half saturation constant for uptake of NH4+ was determined by tuning the growth model to the measured data for April and June. A good match for the 200 and 1000 m stations in June was prioritized as the main goal of the simulation exercises was to indicate the spatial extent of the IMTA effect. The value obtained, = 1.3, compares well with half saturation values for *steady state growth* (Chapman et al., 1978).

**Model simulations and initialization:** Four model simulations with coupled hydrodynamic-ecosystem-kelp model system were run. In the first two, each model grid cell at 5 m depth was initialized with "single kelp plants" with the same initial values (frond area, nitrogen and carbon content: *A*0 = 0.37 cm2, *N*0 = 0.014, *C*0 = 0.24). In the last two simulations (one with and one without a fish farm effluent), the full-scale biomass production potential, and the significance of the IMTA practice in this context, was assessed. Based on the results of the first two runs, we ran simulations representing a large scale (25 ha) kelp installation west of the fish farm in the IA30-zone, with the same plant densities as in the main simulations in Broch et al (2013).

The model domain used had vertical layer thickness ranging from 1 m near the surface up to 50 m at greater depths. The simulation time step used was 6 s.

**Table A1.** Units and description of the variables, parameters and notation relevant for the description of the *S. latissima* growth model updates. All other parameters and their values are described in (Broch and Slagstad 2012, Broch et al. 2013).

|  |  |  |
| --- | --- | --- |
| **Symbol** | **Unit** | **Description** |
| *A* | dm2 | Frond area |
| *N* | g N (g structural dry weight)-1 | Internal nitrogen (nitrate) reserves |
| *C* | g C (g structural dry weight)-1 | Carbon reserves |
| *C*min | g C (g structural dry weight)-1 | Minimum carbon reserve level |
| *N*min | g N (g structural dry weight)-1 | Minimum nitrogen reserve level |
| *N*max | g N (g structural dry weight)-1 | Maximum nitrogen reserve level |
| *N*struct | g N (g structural dry weight)-1 | Structural nitrogen content |
| *KX* | µ mol L-1 | Half saturation constant for uptake of chemical compound *X* ( *X* = NO3- ,NH4+) |
| *JX* | g N dm-1h-1 | Uptake rate for chemical compound *X* ( *X* = NO3- ,NH4+) |
| *JX,*max | g N dm-1h-1 | Maximal theoretical uptake rate for chemical compound *X* ( *X* = NO3- ,NH4+) |
| *µX* | d-1 | Frond area specific growth rate limited by compound or variable *X* |
| *fµ* = *fT f*area*f*photoperod | d-1 | Maximum area specific growth rate depending on temperature, size and time of year |
| *f*curr | --- | Effect of water current speed on nutrient uptake rates |
| *kA* | g dm-2 | Structural dry weight per unit frond area |