Force balance equation

Where

Where V is the volume of water displaced, M is the mass of the frond, *Ca* is added mass (=3) and is water density (1025).

Where *g* is the acceleration due to gravity (9.81), is the overall density of macrocystis. Average buoyancy was measured as 2.49 N.

Where **ur** is the velocity of water relative to the point element, *A* is the maximal projected area

*Sd* is a dimensionless empirical coefficient (*Sd* = 0.0148).

Where ***ar*** and ***aw*** are the acceleration of water relative to the frond, and the acceleration of the water column.

Where *Axs* is the cross sectional area of the stipe (*Axs*=4.1×10-5 m2) and is the angle the frond makes with regard to the seabed

Wave induced velocity

Wave induced acceleration

Wave parameters

where *L* is the wavelength, and T is the wave period. Maximum wave height can be approximated according to:

Where *Hs* is the significant wave height and *t* is the period over which the wave conditions are prevalent.

The maximum tension force can be converted to a stress according to

This is then converted to a breakage probability according to

X Component

Collecting terms

Y component

Collecting terms

Options for Runge kutta

Simulations ran with

Wave height = 3, Wave Period = 12, Depth = 15, Length = 12, length.sim=100, t.step=0.001

Option 1 (trial 1)

Original coding (only the velocity changes)

Option 2 (trial 2)

Coded such that the runge kutta method obeys the following

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Simulation parameters | | | | Time step (Δt) | | | | | | | | | | | | | | |
| 0.05 | | | 0.02 | | | 0.01 | | | 0.005 | | | 0.001 | | |
| Depth | H | T | L | Fmax | Pbreak | Comp Time | Fmax | Pbreak | Comp Time | Fmax | Pbreak | Comp Time | Fmax | Pbreak | Comp Time | Fmax | Pbreak | Comp Time |
| 10 | 2.8 | 7.6 | 42 | 27.50 | 0.30 | 4.5 | 27.51 | 0.30 | 11.5 | 27.52 | 0.30 | 21.0 | 27.52 | 0.30 | 41.0 | 27.52 | 0.30 | 204.0 |
| (-0.05) | (-0.18) | (-0.01) | (-0.04) | (0.00) | (0.00) | (0.00) | (0.00) |
| 7.75 | 1.5 | 6.8 | 26 | 22.99 | 0.15 | 4.3 | 22.99 | 0.15 | 11.0 | 22.99 | 0.15 | 23.0 | 22.99 | 0.15 | 42.0 | 22.99 | 0.15 | 217.0 |
| (-0.04) | (-0.15) | (0.00) | (-0.02) | (0.00) | (-0.02) | (0.00) | (0.00) |
| 6.25 | 3 | 7.6 | 38 | 46.51 | 2.12 | 4.4 | 46.53 | 2.13 | 11.7 | 46.54 | 2.13 | 24.0 | 46.54 | 2.13 | 42.0 | 46.54 | 2.13 | 210.0 |
| (-0.06) | -0.23 | (-0.02) | (-0.08) | (0.00) | (-0.01) | (0.00) | (-0.01) |
| 12.5 | 3 | 7.6 | 40 | 18.63 | 0.07 | 4.2 | 18.63 | 0.07 | 11.5 | 18.63 | 0.07 | 23.0 | 18.63 | 0.07 | 44.0 | 18.63 | 0.07 | 218.0 |
| (-0.02) | (-0.08) | (0.00) | (-0.01) | (0.00) | (-0.01) | (0.00) | (0.00) |
| 5 | 1.7 | 7.8 | 38 | 35.23 | 0.75 | 4.3 | 35.27 | 0.76 | 10.4 | 35.28 | 0.76 | 22.0 | 35.28 | 0.76 | 44.0 | 35.28 | 0.76 | 220.0 |
| (-0.15) | (-0.55) | (-0.03) | (-0.09) | (0.00) | (-0.02) | (0.00) | (-0.01) |
| 3.25 | 1.7 | 7.4 | 28 | 48.44 | 2.47 | 4.6 | 48.50 | 2.48 | 11.4 | 48.50 | 2.48 | 21.0 | 48.50 | 2.48 | 44.0 | 48.50 | 2.48 | 216.0 |
| (-0.12) | (-0.45) | (0.00) | (0.00) | (-0.01) | (-0.02) | (0.00) | (-0.02) |
| 14 | 2.8 | 8 | 44 | 16.60 | 0.05 | 4.3 | 16.60 | 0.05 | 11.3 | 16.60 | 0.05 | 21.0 | 16.60 | 0.05 | 43.0 | 16.60 | 0.05 | 230.0 |
| (0.00) | (-0.01) | (0.00) | (-0.01) | (0.00) | (-0.01) | (0.00) | (0.00) |
| 23 | 4 | 8.6 | 74 | 9.83 | 0.01 | 4.5 | 9.84 | 0.01 | 10.8 | 9.84 | 0.01 | 23.0 | 9.84 | 0.01 | 44.0 | 9.84 | 0.01 | 239.3 |
| (-0.04) | (-0.16) | (0.00) | (-0.01) | (0.00) | (-0.01) | (0.00) | (0.00) |
| 3.25 | 2 | 6.2 | 22 | 55.54 | 4.09 | 4.4 | 55.55 | 4.09 | 11.0 | 55.55 | 4.09 | 24.0 | 55.55 | 4.09 | 46.0 | 55.55 | 4.09 | 235.0 |
| (-0.01) | (-0.03) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| 6.75 | 2.2 | 6.6 | 32 | 35.29 | 0.76 | 4.5 | 35.29 | 0.76 | 11.1 | 35.29 | 0.76 | 23.0 | 35.29 | 0.76 | 43.8 | 35.29 | 0.76 | 262.0 |
| (0.00) | (0.00) | (0.00) | (-0.01) | (0.00) | (-0.01) | (0.00) | (0.00) |
| 7.25 | 1.3 | 6.8 | 23 | 20.81 | 0.11 | 4.5 | 20.83 | 0.11 | 11.2 | 20.83 | 0.11 | 22.0 | 20.83 | 0.11 | 46.0 | 20.83 | 0.11 | 220.0 |
| (-0.11) | (-0.39) | (-0.01) | (-0.05) | (0.00) | (0.00) | (0.00) | (0.00) |
| 7 | 2.2 | 7 | 30 | 31.95 | 0.52 | 4.4 | 31.95 | 0.52 | 11.2 | 31.95 | 0.52 | 22.0 | 31.95 | 0.52 | 44.0 | 31.95 | 0.52 | 247.0 |
| (-0.01) | (-0.04) | (-0.01) | (-0.05) | (0.00) | (-0.01) | (0.00) | (0.00) |
| 12.5 | 6 | 9 | 72 | 95.64 | 27.41 | 4.2 | 95.65 | 27.42 | 10.6 | 95.65 | 27.42 | 22.0 | 95.66 | 27.42 | 46.0 | 95.66 | 27.42 | 211.0 |
| (-0.02) | (-0.07) | (0.00) | (-0.01) | (0.00) | (-0.01) | (0.00) | (0.00) |
| **Average absolute error (%)** | | | | **0.05** | **0.18** |  | **0.01** | **0.03** |  | **0.00** | **0.01** |  | **0.00** | **0.00** |  |  |  |  |