1) mixed layer depth: 20 m
primary productivity: 20 $mg\,C\,m^{-3}\,day^{-1}$

20 mg = .02 g

Moles C/day = $\frac{.02\,g}{12g/mol}$ = .0016666667 $mol\,C\,m^{-3}\,day^{-1}$

Moles N/day = .0016666667$\left(\frac{16}{106}\right)$ = 0.000251572 $mol\,N\,m^{-3}\,day^{-1}$

Moles P/day = .0016666667$\left(\frac{1}{106}\right)$ = 0.000015723 $mol\,P\,m^{-3}\,day^{-1}$

Available NO_3:

1 μmol = 10^{-6} mol/L
.25 μM = .25 × 10^{-6} mol/L
1 m^3 = 1000 L
$\frac{.25\times10^{-6}\,mol}{\cancel{1L}} \times \frac{1000\,\cancel{L}}{1\,m^3}$ = .00025 mol/m^3

Available PO_4:

0.0125 μM = 0.0125 × 10^{-6} mol/L
$\frac{0.0125\times10^{-6}\,mol}{\cancel{1L}} \times \frac{1000\,\cancel{L}}{1\,m^3}$ = 0.0000125 mol/m^3

Total mol in 20 m:
V = 20 m × 1 m^2 = 20 m^3

Total NO_3:
$\frac{.00025\,mol}{1\,\cancel{m^3}} \times 20\,\cancel{m^3}$ = 0.005 mol N

Total PO_4:

$$\frac{0.0000125 \text{ mol}}{1 \text{ m}^3} \times 20 = 0.00025 \text{ mol P/m}^3$$

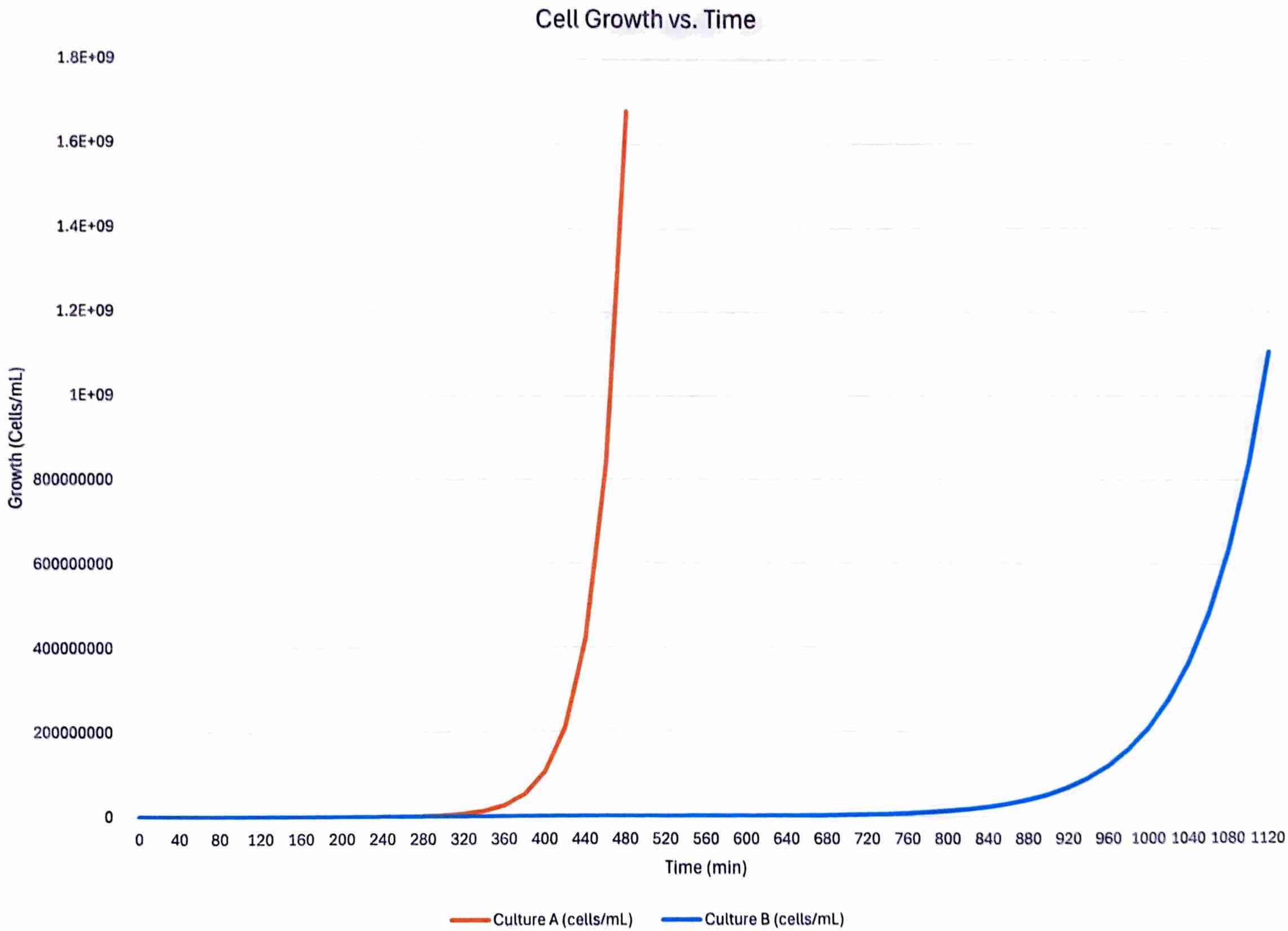
Time for N to run out:

$$\text{Time (N)} = \frac{0.005 \cancel{\text{mol}}/\cancel{\text{m}^3}}{0.000251572 \cancel{\text{mol}}\,\cancel{\text{m}^{-3}}\,\text{day}^{-1}} = \boxed{19.8 \text{ days}}$$

Time for P to run out:

$$\text{Time (P)} = \frac{0.00025 \cancel{\text{mol}}/\cancel{\text{m}^3}}{0.000015723 \cancel{\text{mol}}\,\cancel{\text{m}^{-3}}\,\text{day}^{-1}} = \boxed{15.9 \text{ days}}$$

This makes phosphate the limiting factor since it will only last 15.9 days while the nitrate will last 19.8 days



Cell Growth vs. Time
Growth (Cells/mL)
1.8E+09
1.6E+09
1.4E+09
1.2E+09
1E+09
800000000
600000000
400000000
200000000
0
0 40 80 120 160 200 240 280 320 360 400 440 480 520 560 600 640 680 720 760 800 840 880 920 960 1000 1040 1080 1120
Time (min)
Culture A (cells/mL)
Culture B (cells/mL)

2) $N(t) = N_0 \times 2^{\frac{t}{T}}$

Culture A:

$\frac{10^9}{100} = \frac{100 \times 2^{\frac{t}{20}}}{100}$

$10^7 = 2^{\frac{t}{20}}$

$(20)\log_{(2)}(10^7) = \frac{t}{20}(20)$

$20 \times \log_{(2)}(10^7) = t$

$\boxed{t = 464.5 \Rightarrow 465 \text{ min}}$

Culture B:

$\frac{10^9}{200} = \frac{200 \times 2^{\frac{t}{50}}}{200}$

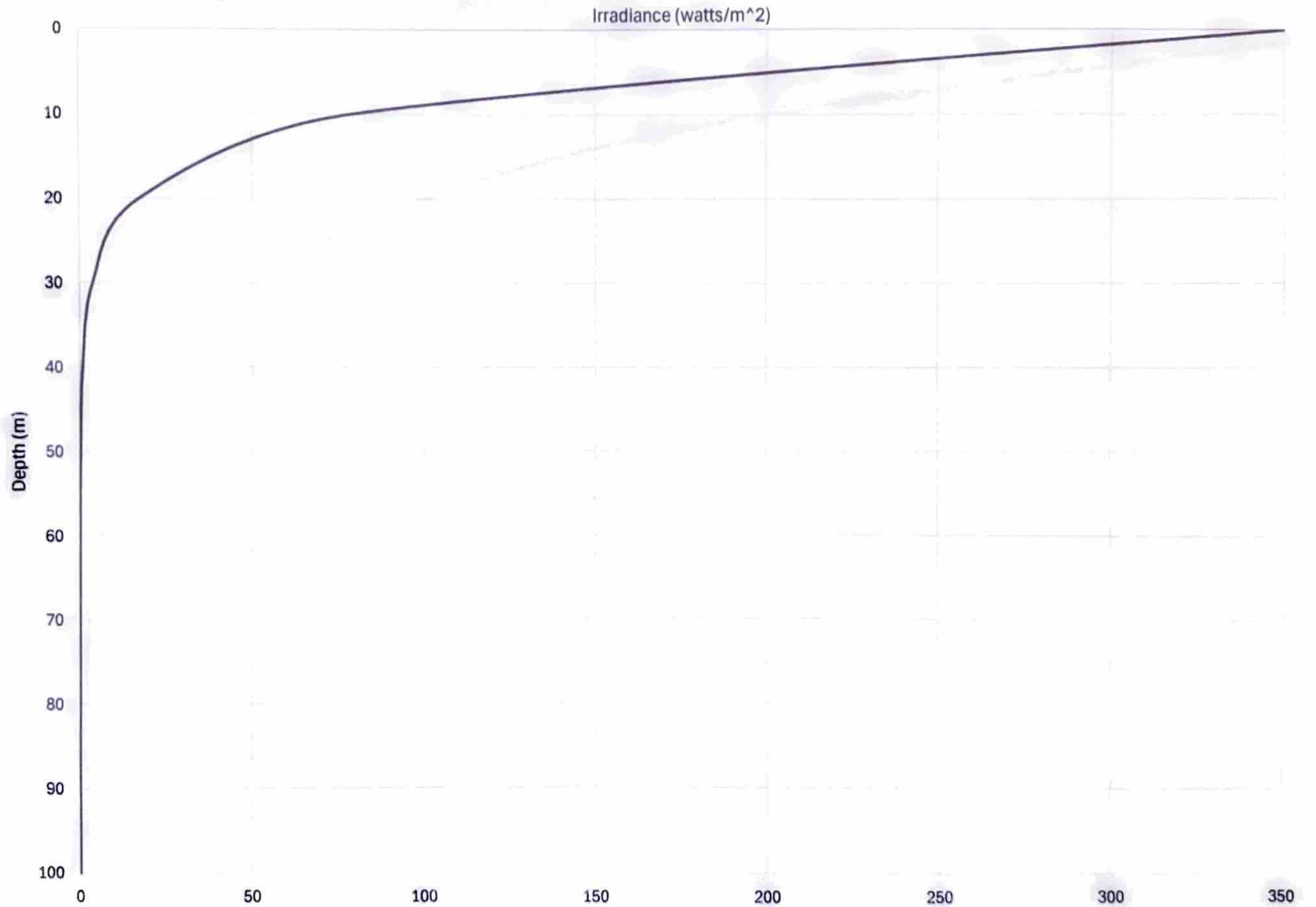
$5000000 = 2^{\frac{t}{50}}$

$(50)\log(2)(5000000) = \frac{t}{50}(50)$

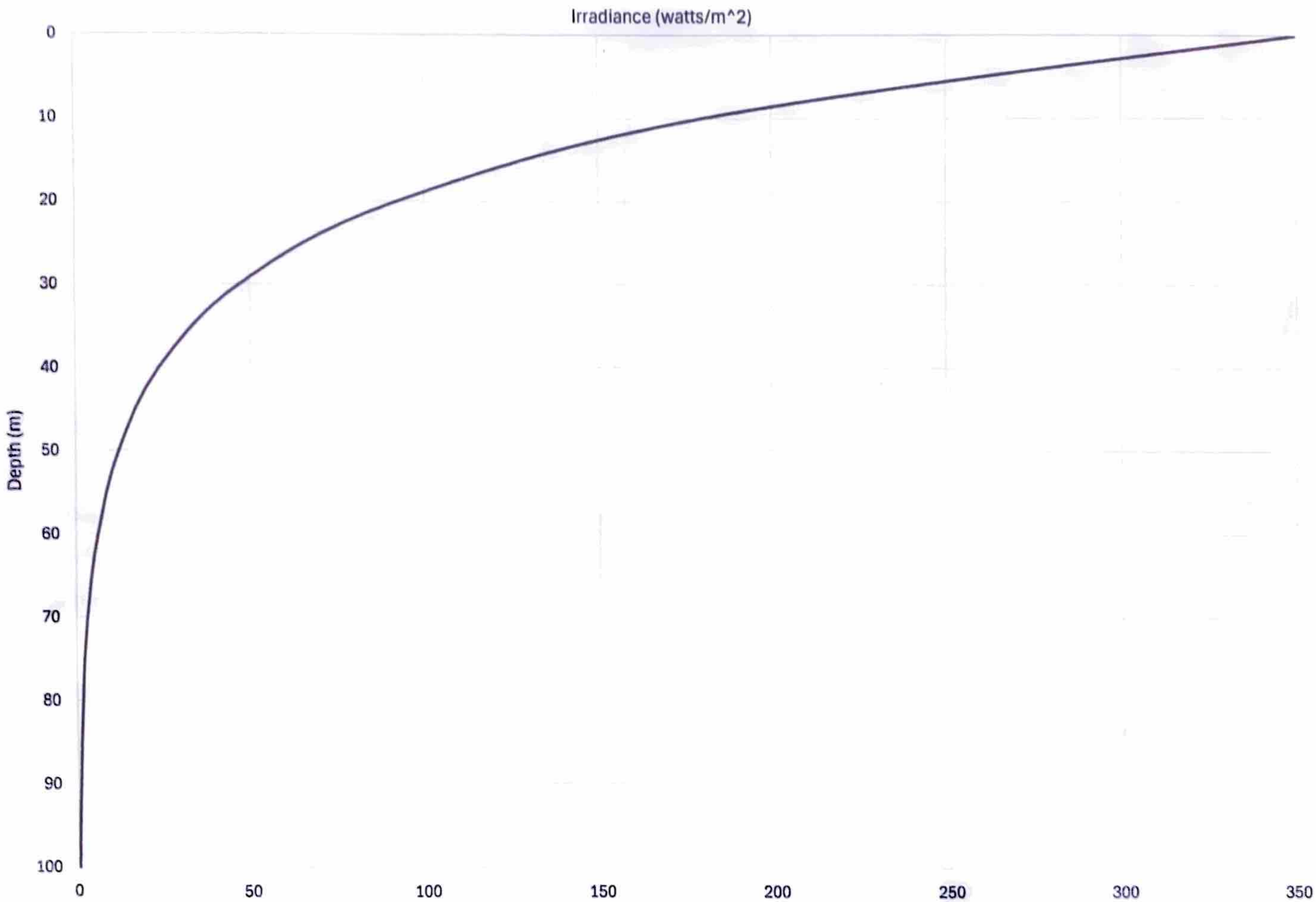
$t = 50 \log(2)(5 \times 10^6)$

$\boxed{t = 1112 \text{ min}}$

Depth vs. Irradiance for Coefficient 0.15



Depth vs. Irradiance for Coefficient 0.067



3) $I(z) = I_0 e^{-kz}$

$I_0 = 350\ w/m^2$
$k_1 = 0.067$
$k_2 = 0.15$
z = depth
$e = \ln$

Coefficient 0.067:
$I(10m) = 350\ watt/m^2\ e^{-0.067(10)}$
$= 179.1\ watt/m^2$
$I(20m) = 350\ watt/m^2\ e^{-0.067(20)}$
$= 91.6\ watt/m^2$
$I(30m) = 46.9\ watt/m_2$
$I(40m) = 23.997 \Rightarrow 24\ watt/m^2$
$I(50m) = 12.3\ watt/m^2$
$I(60m) = 6.28\ watt/m^2$
$I(70m) = 3.22\ watt/m^2$
$I(80m) = 1.65\ watt/m^2$
$I(90m) = 0.84\ watt/m^2$
$I(100m) = 0.431\ watt/m^2$

Coefficient 0.15
$I(0m) = 350\ watt/m^2$
$I(10m) = 350\ watt/m^2\ e^{-0.15(10m)}$
$= 78.1\ watt/m^2$
$I(20m) = 350\ watt/m^2\ e^{-0.15(20)}$
$= 17.43\ watt/m^2$
$I(30m) = 17.4\ watt/m^2$
$I(40m) = 3.88\ watt/m^2$
$I(50m) = 0.87\ watt/m^2$
$I(60m) = 0.194\ watt/m^2$
$I(70m) = 0.043\ watt/m^2$

$I(80m) = 0.0022$ watt/m^2
$I(90m) = 0.00048$ watt/m^2
$I(100m) = 0.00012$ watt/m^2

$$I(z) = I_o e^{-kz}$$

$$.01 = e^{-kz}$$

$$\ln(0.01) = -kz$$

$$-k \qquad -k$$

$$z = \frac{\ln(0.01)}{-0.067} = \boxed{68.73 \text{ m}}$$

$$z = \frac{\ln(0.01)}{-0.15} = \boxed{30.7 \text{ m}}$$

The water with a coefficient of 0.067 has the greatest net primary productivity of the two because the light reaches 38.03 m deeper than the water with a coefficient of 0.15, thus increasing the overall productivity.