Student Number: ____________________ Name: ____________________________

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION

December 21, 2001

EDV 220F — ENGINEERING ECOLOGY

Exam Type: A

Examiner: D.M. Bagley

Special Instructions

1. Do not begin until instructed to do so.
2. This exam accounts for 55% of your final grade. There are 10 questions worth a total of 125 points. The value of each question is shown with the question.
3. Place your name and student number at the top of each page.
4. Any non-programmable electronic calculator may be used.
5. Use the backs of the sheets if necessary but please clearly label your solutions.
6. The last page contains equations that may be useful and may be removed.

Problem	Mark	Possible
1		13
2		4
3		15
4		22
5		5
6		20
7		6
8		14
9		8
10		18
Total		125

Student Number:________________ Name: ____________________

Problem 1 (13 pts)

An ecologist is attempting to determine the appropriate equation to describe growth for a population growing in the absence of competition or predation. The population was 75 organisms 10 years ago and is 90 organisms today. Two growth equations are being considered:

1. Exponential growth, and

2. $$\frac{dN}{dt} = r'N \quad \text{where} \quad r' = r_o e^{-kt}$$

   which integrates to $N = N_o \exp\left(\frac{r_o}{k}\left[1 - e^{-kt}\right]\right)$

a) If the population is growing exponentially, what is the net specific growth rate, r? (3 pts)

b) Assume for the second equation that $r_o = 0.02\ \text{yr}^{-1}$ when $N_o = 75$ organisms and $k = 0.025\ \text{yr}^{-1}$. Compare the doubling times to go from 75 organisms to 150 organisms for the two growth equations. (6 pts)

Student Number:____________________ Name: ________________________

Problem 1 (continued)

c) When will the population reach 300 organisms? (4 pts)

i) Assuming exponential growth?

ii) Assuming the second growth equation?

Problem 2 (4 pts)

a) What functions are provided by the polyurethane foam cubes used in the Waterloo Biofilter described by Dr. Jowett at the Dec. 3 tutorial? (2 pts)

b) In her talk at the Nov. 12 tutorial, Ms. Foster indicated that many of our historical designs followed a "take-make-waste" production-consumption model. Briefly explain using ecological concepts why this historical approach is not sustainable. (2 pts)

Student Number:________________ Name: ______________________

Problem 3 (15 pts)

Define the following terms (1.5 pts each):

a) Engineering

b) Ecology

c) Carrying Capacity

d) Keystone Species

e) Population

Student Number:____________________ Name: ____________________________

Problem 3 (continued)

f) Climax Stage

g) Remediation

h) Sustainable Development

i) Engineering Design

j) Design for the Environment

Student Number:____________ _____ Name: ________________________

Problem 4 (22 pts)

a) List the four (4) steps in an inventory analysis (4 pts)

b) List five (5) examples of engineered infrastructure (5 pts)

c) Will a non-biodegradable, water soluble compound bioaccumulate? Explain. (2 pts)

d) Are organisms a replaceable resource? Explain. (2 pts)

e) Name three (3) products that could be recovered from municipal wastewater. (3 pts)

Student Number:________________ Name: ______________________

Problem 4 (continued)

f) Name four (4) possible solutions for the problem of reducing the pool of atmospheric CO_2 while maintaining sufficient energy production. (4 pt)

g) Describe without using numbers how the combustion of fossil fuels changed the sulfur cycle. (2 pt)

Problem 5 (5 pts)

How many square meters of active photosynthesis would be required to capture the power equal to that required to move water from the bottom to the top of Niagara Falls using only solar energy (in other words, not using pumps)? Assume photosynthesis captures 168,000 kJ per square meter per year, the energy required to evaporate water is 2,255 kJ/kg, Niagara Falls is 50 m high and Niagara Falls has a flow of approximately 5.7×10^6 kg/s.

Student Number:________________ Name: ______________________

Problem 6 (20 pts)

A wastewater treatment facility discharges a flow of 1.5 m^3/s into a receiving water. During a BOD measurement conducted with 50 mL of sample in a 300-mL sample bottle, the initial dissolved oxygen concentration (after dilution) was 8.0 mg/L. The dissolved oxygen concentration after 5 days of incubation at 20°C was 2.2 mg/L. The receiving stream temperature is 15°C after mixing with the wastewater. Upstream of the discharge point, the BOD_L concentration is 10 mg/L, the dissolved oxygen concentration is 7.2 mg/L and the flow is 8 m^3/s. The saturation oxygen concentration in the stream at 15°C is 9.6 mg/L and the cross sectional area of the stream is 150 m^2. Assume that k_1 is 0.25 day^{-1} at 20°C, k_2 is 0.15 day^{-1} at 20°C and $\theta = 1.047$. If the dissolved oxygen concentration in the stream 5.5 km downstream of the discharge point is 4.0 mg/L, what is the critical oxygen concentration and where does it occur? Use the back of the previous page if more space is needed.

Student Number:________________ Name: ______________________

Problem 7 (6 pts)

The raccoon population in an urban gorge is currently 50 raccoons. The birth rate this year is 120 raccoons/year and the death rate this year is 118 raccoons/year. The carrying capacity is 40 raccoons.

a) What is the probability of extinction today? Assume that there is no permanent migration of raccoons into or out of the gorge and no significant competition or predation. (2 pts)

b) What is the raccoon population in 5 years? (4 pts)

Student Number:__________________ Name: __________________________

Problem 8 (14 pts)

a) A section of an organism's DNA sequence is CCA–AAG–GCA. Due to excessive exposure to ultraviolet light the sequence becomes CCA–AGG–GCA. Name what has happened and describe how it will affect the organism. (4 pts)

b) Brook trout are native to many water bodies in the eastern half of Canada. If rainbow trout are introduced into one of those water bodies, what will be the population of each fish in that water body after a long period of time? Assume brook and rainbow trout compete for identical resources. (4 pts)

Student Number:__________________ Name: _________________________

Problem 8 (continued)

c) The conversion of less useful solar energy to highly useful chemical energy during photosynthesis appears to decrease entropy. Explain why the 2nd Law of Thermodynamics has not been violated. (2 pts)

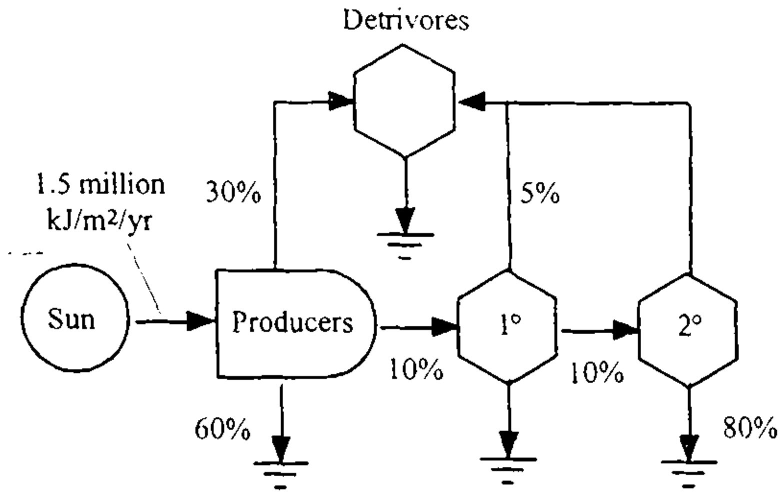
d) Are the following equations suitable to be used for examining island biogeography questions? If not, list and explain each error. (4 pts)

$$I = K_I \cdot A \cdot S^{0.2} e^{-d} \qquad E = \frac{K_E A^{0.1} S^2}{d^{1.2}}$$

Student Number:________________ Name: ______________________

Problem 9 (8 pts)

A simplified ecosystem with an area of 2.3 km^2 has primary producers, consumers and detrivores with the energy movement as shown in the diagram.



a) At steady-state, how much energy is available per year for the 2°(secondary) consumers? (3 pts)

b) At steady-state, how much energy per year do detrivores transform to waste heat? (3 pts)

c) At steady-state, how much of the entering energy overall is transformed to waste heat? (2 pts)

Student Number:________________ Name: ______________________

Problem 10 (18 pts)

Grizzly bears on the Pacific coast are known to consume large quantities of salmon when the salmon return to the rivers to spawn. Being messy eaters, the bears leave partially eaten salmon carcasses on the forest floor which provide food for other organisms, such as ravens. The following equations attempt to describe this situation.

Salmon growth rate: $r_S S\left(\frac{K_S - S}{K_S}\right)$

Salmon harvest rate due to human fishing: Variable

Grizzly bear growth rate: $r_B B\left(\frac{K_B - B}{K_B}\right)$

Grizzly bear carrying capacity: $K_B = K_{Bmax}\left(\frac{S}{K_S}\right)$

Raven growth rate: $r_R R\left(\frac{K_R - R}{K_R}\right)$

Raven migration rate out of the area: $r_M R\left(\frac{M_B}{M_B + B}\right)$

Where: S = salmon population B = grizzly bear population R = raven population

$r_S = 0.05\ yr^{-1}$ $K_S = 1 \times 10^6$ salmon $r_B = 0.02\ yr^{-1}$ $K_{Bmax} = 60$ bears

$r_R = 0.02\ yr^{-1}$ $K_R = 100$ ravens $r_M = 0.01\ yr^{-1}$ $M_B = 60$ bears

a) What is the steady-state raven population if the salmon harvest rate is 2,000 salmon/yr? Use the back of the previous page is more space is needed. (10 pts)

Student Number:____________________ Name: ____________________________

Problem 10 (continued)

b) What is the maximum salmon harvest rate that will allow steady state to be achieved? (4 pts)

c) Population equations are necessarily approximations. To test the appropriateness of the equations used in this problem, determine the steady-state bear population when the steady-state salmon population is 0. Why isn't this result reasonable ecologically? Propose an alternative formula that is more reasonable. (4 pts)

Student Number:________________ Name: ______________________

Equations that may be useful. You may tear this page off to more easily reference the equations.

$$\frac{dN}{dt} = r \cdot N \qquad \frac{dN}{dt} = r \cdot N\left(\frac{K-N}{K}\right) \qquad N = \frac{KN_o e^{rt}}{K - N_o + N_o e^{rt}}$$

$$N = N_o e^{rt} \qquad \frac{dN_1}{dt} = r_1 N_1\left[\frac{(K_1 - \alpha N_2) - N_1}{K_1}\right] \qquad \frac{dN_2}{dt} = r_2 N_2\left[\frac{(K_2 - \beta N_1) - N_2}{K_2}\right]$$

$$N_1 = K_1 - \alpha N_2 \qquad N_2 = K_2 - \beta N_1 \qquad N_1 = \frac{K_1 - \alpha K_2}{1 - \alpha\beta} \qquad N_2 = \frac{K_2 - \beta K_1}{1 - \alpha\beta}$$

$$\text{probability of extinction} = \left(\frac{d}{b}\right)^{N_o} \qquad L_o = \frac{y}{1 - e^{-k_1 t}} \qquad y = \frac{(DO_i - DO_f)V_b}{V_s}$$

$$r_{O2} = k_1 L \qquad r_R = k_2(C_s - C) \qquad \frac{\partial C}{\partial t} = \bar{D}_x \frac{\partial^2 C}{\partial x^2} - \bar{v}_x \frac{\partial C}{\partial x} + \sum \textit{reactions}$$

$$k_{1,T_2} = k_{1,20}\theta^{T_2 - 20} \qquad Q = \bar{v}_x A \qquad \theta_H = \frac{xA}{\bar{v}_x A} = \frac{x}{\bar{v}_x}$$

$$D = \frac{k_1 L_o}{k_2 - k_1}\left(e^{-k_1\theta_H} - e^{-k_2\theta_H}\right) + D_o e^{-k_2\theta_H} \qquad D = C_s - C \qquad D_c = \frac{k_1}{k_2} L_o e^{-k_1\theta_H^*}$$

$$\theta_H^* = \frac{1}{k_2 - k_1}\ln\left[\frac{k_2}{k_1}\left(1 - \frac{D_o(k_2 - k_1)}{k_1 L_o}\right)\right]$$

For $ax^2 + bx + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$t_d = \ln 2 / r$ Hydraulic retention time = V / Q $V = \text{depth} \cdot \text{area}$

Potential energy $= m \cdot g \cdot h$ $g = 9.81\ m/s^2$