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1.018/7.30J
Fundamentals of Ecology

November 25, 2003

Quiz 3: Population Ecology

Potentially useful information:

$dN/dt = rN((K-N)/K)$

$dN_1/dt = r_1N_1((K_1 - N_1 - \alpha N_2)/K_1)$

$R_o = \Sigma\, l_x b_x$

$T = T_s + T_h P_e$

$P_e = (a'NT)/(1+a'T_hN)$

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1. Milfoil, an invasive species of algae, has been spreading across the country and is choking out the native algae populations. You're concerned about the lakes in your region, and decide to analyze the competition between algae in your region and milfoil, as well as the predatory responses of algae consumers.

   You begin by growing a native freshwater algae species, *Spirogyra*, in an artificial pond in your lab. The water in this pond contains 100 mM nitrogen, 15 mM phosphorus, and an abundance of other nutrients. You collect the following data over time:

Days	Cells (x 10^6)
0	40
1	110
2	299
3	785
4	2130
5	4252
6	6381
7	7029
8	7235
9	7302

(a) What is the intrinsic growth rate for *Spirogyra*, r ? (include units!) (4 pts)

Different approaches possible. The easiest way is to assume that Day 0 to Day 1 is most likely to represent just exponential growth (no intraspecific competition), so that dN/dt = rN describes growth with no need for logistic equation

So we can use $N=N_0e^{rt}$ with N=110, N_0=40, t = 1 day

$\ln(110/40) = r*(1\text{ day}) \implies$ $\boxed{r = 1.0\text{ day}^{-1}}$

You could also use the logistic equation and use K_1 as estimated in (b). Then pick two points and solve for r. The only tricky part is what to use for N. (probably should be an average of the two values)

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(b) Estimate the carrying capacity, K_1, for *Spirogyra* in this pond and explain. (6 pts)

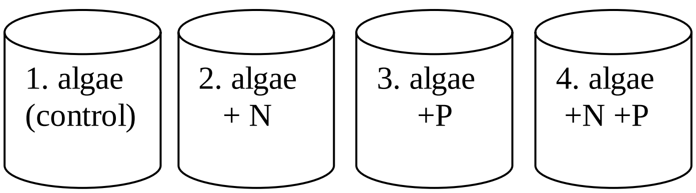
Based on data in table, it appears that the rate of growth has nearly leveled out and reached the carrying capacity. Estimated value should be approximately $7300\text{-}7400 \times 10^6$ cells

(c) What do you suspect is the limiting factor for the growth of *Spirogyra*? Assume that the *Spirogyra* are not limited by light. Explain your answer. (6 pts)

The N:P ratio in solution is approximately 6.6:1, whereas according to the Redfield ratio, organisms generally require N and P to be supplied at a ratio of 16:1. The fact that N:P is lower than the Redfield N:P suggests that N will be the limiting nutrient.

(d) How would you test whether this is actually the limiting factor? Briefly describe your experiment. (6 pts)

Start with new ponds or ponds separated into sections or bottles. Grow algae with either (1) the same solution (control), (2) solution with increased N, (3) solution with increased P, (4) solution with N and P (this one is optional), and maybe (5) solution with Fe or other nutrients.



If N is limiting, there should be increased growth in 2 and 4 relative to 1, and 1 and 3 should be the same.

2. To study the interactions of *Spirogyra* and milfoil, you start with another pond, same size, with the same initial solution. You add samples of both kinds of algae and give them sufficient equilibration time so that their populations stabilize. You observe that the two species coexist.

(a) Since the species are coexisting, is inter- or intra- specific more important in limiting the population size of these two algae populations? Why? (6 pts)

Intraspecific competition, meaning that the populations limit themselves rather than acting as strong competitors against each other. In situations where one or both species acts as a strong interspecific competitor, there is no coexistence.

(b) Given your answer in 1(c) about the limiting factor for the growth of *Spirogyra*, what can you say about the limiting factor for milfoil? (6 pts)

The limiting factor for milfoil cannot be N, or else whichever algae species was more efficient at using N would outcompete the other species, according to the competitive exclusion principle. The most likely limiting factor is light, or perhaps P, or another nutrient.

(c) Huffaker performed some experiments in order to determine conditions necessary for the coexistence of two species. What did Huffaker demonstrate in his experiments? Are his results relevant to the interactions of *Spirogyra* and milfoil? Why or why not? (6 pts)

Huffaker demonstrated that environmental heterogeneity was essential for providing sanctuaries for prey to reproduce and hide from predators. His experiments involved herbivore mites that ate oranges, and carnivore mites that ate the herbivore mites. Only when the conditions were sufficiently complex could the herbivore mites coexist with their predators.

These results are not directly relevant to the *Spirogyra* and milfoil interactions, since Huffaker studied predator-prey interactions, whereas the algae are exhibiting interspecific competition.

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Based on a previous experiment, you have determined the carrying capacity for the milfoil, K_2, for this pond is 5000×10^6 cells.
In the pond with both algae species combined, the populations stabilize at $N_1 = 4300 \times 10^6$ (*spirogyra*) and N_2 (milfoil) $= 2600 \times 10^6$.

(d) Calculate α, the competitive effect of N_2 on N_1, and β, the competitive effect of N_1 on N_2. (7 pts)

The equilibrium point will occur when $dN_1/dt = dN_2/dt = 0$

$$dN_1/dt = 0 = r_1N_1((K_1 - N_1 - \alpha N_2)/K_1) \rightarrow K_1 - N_1 - \alpha N_2 = 0$$

$$\alpha = (K_1 - N_1)/N_2 = (7350 - 4300)/2600 = \boxed{1.2}$$

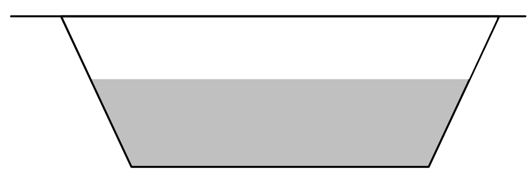
$$dN_2/dt = 0 = r_2N_2((K_2 - N_2 - \beta N_1)/K_2) \rightarrow K_2 - N_2 - \alpha N_1 = 0$$

$$\beta = (K_2 - N_2)/N_1 = (5000 - 2600)/4300 = \boxed{0.55}$$

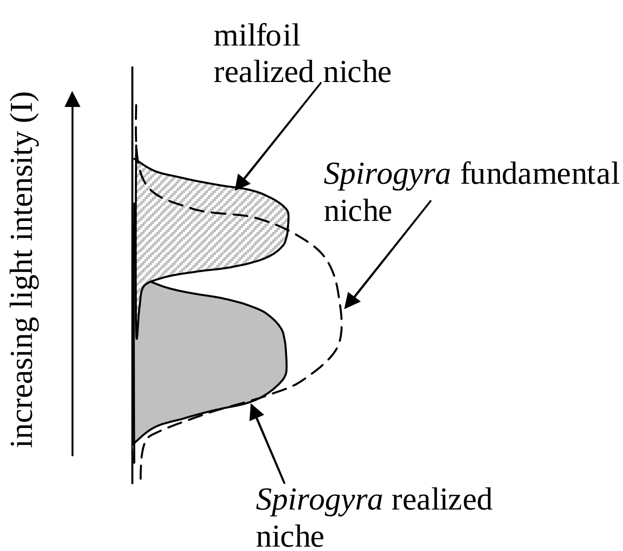
3. In addition to calculating the total populations of both species of algae, you also observe the spatial distribution of the algae within your pond. When the *Spirogyra* grows by itself, it is present throughout the pond (as shown below, left, in the shaded gray area). When *Spirogyra* is grown in the presence of milfoil, its distribution changes, and it grows only in the bottom of the pond, as shown below, right, in the gray shaded area.

***Spirogyra* alone**

***Spirogyra* with milfoil present**



You know that milfoil can only grow at high light intensity. Discuss the change in the S*pirogyra* distribution in the context of niches and graphically depict the reason for the change. (9 pts)



The fundamental niche of the *Spirogyra* extends throughout the water column, at all light intensities in the pond. However, because the milfoil can only grow at high light intensities, the realized niche for *Spirogyra* occurs only at lower light intensities, in the lower half of the pond, due to interspecific competition in the high light intensity region (near the top of the pond).

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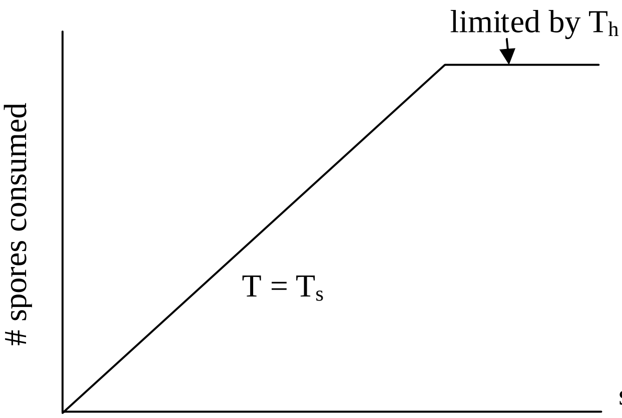
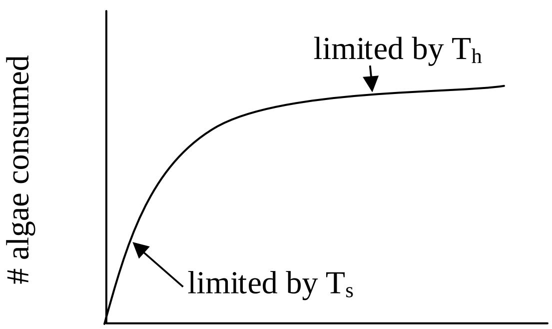
4. You are also interested in how two herbivore populations interact with the algae species. You select two predators: *Daphnia* and a snail. Both species of algae reproduce sexually by producing spores. *Daphnia*, which are filter-feeders, eat only the spores floating in the water and cannot differentiate between *Spirogyra* and milfoil spores. Snails eat only the algal tissues (not spores), and exhibit a strong preference for eating the *Spirogyra*.

(a) You begin by studying the rate of consumption of *Spirogyra* spores by *Daphnia*. Sketch the Holling functional response curve for number of spores eaten as a function of spore density and explain. Label the axes. What type of functional response is this (*i.e.*, Type I, II or III)? On your graph, label the regions where *Daphnia* are limited by search time or by handling time. (6 pts)



Daphnia and other filter-feeders exhibit Type I functional response curves, where handling time T_h=0 and number of prey consumed is linearly related to prey density (until a certain threshold density).

(b) Would you expect the functional response graph to be different for the rate of consumption of the *Spirogyra* tissues by the snail? Would it be the same type of response? Why or why not? (6 pts)



Snails should exhibit a different functional response curve because they have to search out their prey and also have to spend time eating their prey. Most likely, they will exhibit Type II response. At low algae density, the snails will be limited the time it takes to fine prey (search time). As prey density increases, they will be more and more limited by the amount of time it takes them to eat the algae (handling time).

Below is a life table for the *Spirogyra* and the milfoil based on laboratory data when each species was grown individually.

l_x = proportion of organisms surviving from the start of the life table to beginning of each stage of life
b_x = per capita production of spores

	Spirogyra			**milfoil**		
	l_x	**b_x**		**l_x**	**b_x**	
spore	1.0	0		1.0	0	
adult	0.002	5000		0.005	10000	

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(c) Calculate R_o, net productive rate, for the *Spirogyra* and the milfoil and state whether the populations would be expanding or diminishing. Explain how the data in the table would be different in a field study in the presence of predators. (5 pts)

Spirogyra: $R_o = \Sigma l_x b_x = 1.0*0 + 0.002*5000 = \boxed{10}$

milfoil: $R_o = \Sigma l_x b_x = 1.0*0 + 0.005*10000 = \boxed{50}$

Since $R_o > 1$ in both cases, both populations should be expanding.

In the presence of predators, l_x should be lower for both adults and spores, depending on type of predator.

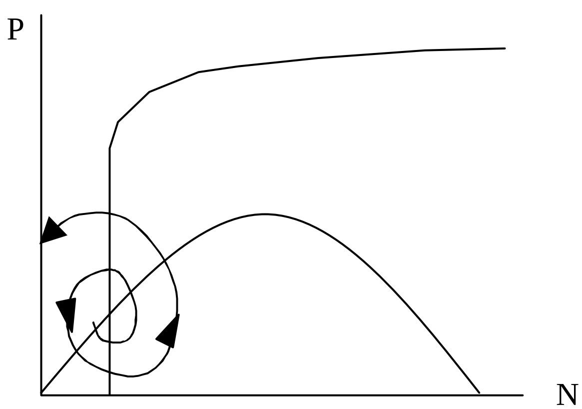
(d) In two additional ponds in your laboratory, you study predation by snails.

In Pond #1, you grow only *Spirogyra* and snails. You observe that the two populations oscillate for a while, and then the snails eventually eat all the *Spirogyra*, causing a crash first in the *Spirogyra* population and then in the snail population.

In Pond #2, you grow only milfoil and snails. You observe that the two populations oscillate for a while, and then come to an equilibrium with stable populations of both species.

Using Rosenweig-MacArthur diagrams (like the ones we drew in class), sketch the isoclines for both predator and prey, and draw in the line showing the changes in populations over time. What can you say about the characteristics of the predator in both cases? (Label your axes). (8 pts)

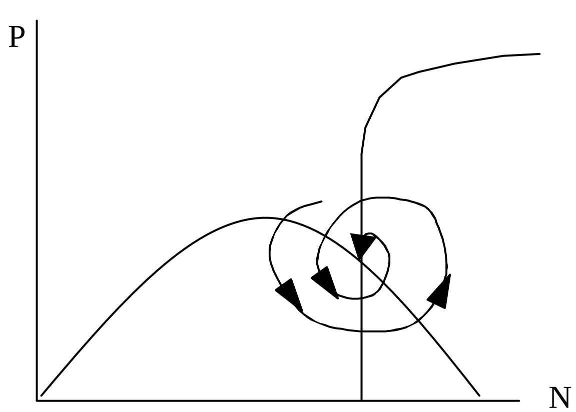
Pond #1



N = *Spirogyra*
P = snail

Here, snail is acting as an efficient predator, so effective that it eats the *Spirogyra* to extinction

Pond #2



N = milfoil
P = snail

Here, snail is acting as an inefficient predator, so that it does not eliminate all of the milfoil, and the two species stably coexist

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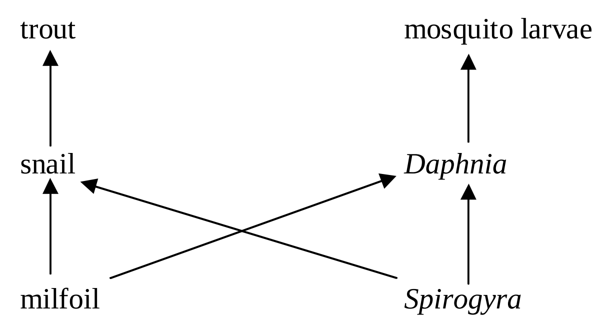
(e) To improve the survival of the *Spirogyra*, you want to take steps that will help their population relative to the milfoil population. Should you to try to decrease predation by *Daphnia* of the spores or predation by snails of the adult algae? Why? (5 pts)

Since the *Daphnia* eat the spores of both the *Spirogyra* and the milfoil, decreasing the predation by *Daphnia* will not really help the *Spirogyra* relative to the milfoil. Since the snails preferentially eat the *Spirogyra* tissues, decreasing snail predation of adult algae tissue will help the *Spirogyra* much more than the milfoil.

(f) In a natural pond system, the snail is eaten by trout, and the *Daphnia* is eaten by mosquito larvae. For the sake of simplicity, assume that nothing else eats the snails or *Daphnia* in this system. Construct a food web for the pond community. (5 pts)



(g) In order to help the *Spirogyra* population, you have a few measures available to you. You can either adjust the trout population (by adding more trout or by encouraging more fishing) or you can adjust the mosquito larvae population (by adding more larvae or by adding a biocide that only affects the mosquito larvae). Which measure be most effective at increasing the population of *Spirogyra*? (5 pts)

Since decreasing the snail population will be most beneficial to *Spirogyra*, and since trout are the sole predators of snails, the most effective way to help *Spirogyra* will be increasing the trout population by adding more trout to the lake.

(h) Suppose that a golf course is built upstream of the pond, and the fertilizers in the runoff cause an increase in the primary productivity of both algae species of 50%. By how much would you expect the productivity of the snail to increase? And for the trout? (4 pts)

The productivity of the snail and of the trout will both increase by 50% (not 5% and 0.5%!).

Assuming a trophic level transfer efficiency of 10%, we can project how the increase in productivity will be echoed throughout the food web.

P = total primary productivity before golf course and 1.5*P = total primary productivity after golf course

productivity of snail before golf course = 0.1*P
productivity of snail after golf course = 0.1*1.5*P

% increase = 100*(0.1*1.5*P – 0.1*P)/(0.1*P) = 50%

n.b. you can see that the value you pick for the trophic level transfer efficiency doesn't matter