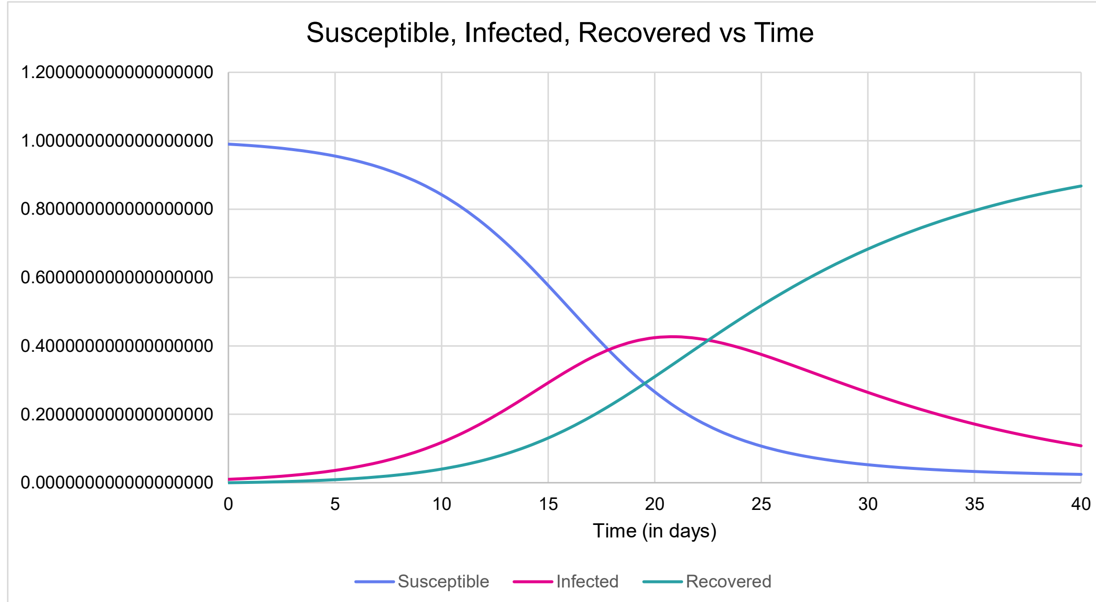
Spread of an Infectious Disease (SIR Model)

Time	Susceptible	Infected	Recovered
0	0.990000000000000000	0.010000000000000000	0.000000000000000000
1	0.986040000000000000	0.012960000000000000	0.001000000000000000
2	0.980928368640000000	0.016775631360000000	0.002296000000000000
3	0.974346091558852000	0.021680345305148300	0.003973563136000000
4	0.965896427674165000	0.027961974659320500	0.006141597666514830
5	0.955093079100503000	0.035969125767049800	0.008937795132446890
6	0.941351533867941000	0.046113758422906700	0.012534707709151900
7	0.923987830978414000	0.058866085470143600	0.017146083551442500
8	0.902231212325715000	0.074736095575828400	0.023032692098456900
9	0.875259517079367000	0.094234181264593700	0.030506301656039700
10	0.842267771484959000	0.117802508732541000	0.039929719782499100
11	0.802579268882761000	0.145710760461485000	0.051709970655753300
12	0.755801494642949000	0.177917458655149000	0.066281046701901800
13	0.702013382173095000	0.213913825259489000	0.084072792567416700
14	0.641945234987496000	0.252590589919139000	0.105464175093366000
15	0.577085504746987000	0.292191261167734000	0.130723234085279000
16	0.509637768173531000	0.330419871624416000	0.159942360202053000
17	0.442279989799590000	0.364735662835916000	0.192984347364494000
18	0.377753875704144000	0.392788210647770000	0.229457913648086000
19	0.318402968142907000	0.412860297144230000	0.268736734712863000
20	0.265820590527273000	0.424156645045441000	0.310022764427286000
21	0.220720762582455000	0.426840808485715000	0.352438428931830000
22	0.183035711082343000	0.421841779137255000	0.395122509780402000
23	0.152150867078892000	0.410542445226981000	0.437306687694127000
24	0.127165111473303000	0.394473956309872000	0.478360932216825000
25	0.107099781622319000	0.375091890529869000	0.517808327847812000
26	0.091030877796698000	0.353651605302503000	0.555317516900799000
27	0.078153591370738700	0.331163731198212000	0.590682677431050000
28	0.067800937400789100	0.308400012048340000	0.623799050550871000
29	0.059437013436272200	0.285923934808023000	0.654639051755705000
30	0.052639227534297700	0.264129327229195000	0.683231445236507000
31	0.047077802032498300	0.243277820008075000	0.709644377959427000
32	0.042496608012803100	0.223531232026963000	0.733972159960234000
33	0.038696880354375600	0.204977836482694000	0.756325283162930000
34	0.035524079228907800	0.187652853959892000	0.776823066811200000
35	0.032857601288267000	0.171554046504544000	0.795588352207189000
36	0.030602859504493000	0.156653383637864000	0.812743756857643000
37	0.028685242908343800	0.142905661870226000	0.828409095221430000
38	0.027045529458853700	0.130254809132694000	0.842699661408452000
39	0.025636405347831500	0.118638452330447000	0.855725142321722000
40	0.024419819966318400	0.107991192478915000	0.867588987554766000

β	0.4
γ	0.1
Total Population	1

Infected (Max)	0.426840808485715000

The number of infected individuals reaches its maximum value at Day 21 (t = 21) with approximately 42.68% of the population infected (I ≈ 0.4268...). After this point, the number of infected individuals begins to decrease



Guide Questions:

What happens when you increase the recovery rate γ?

Increasing the recovery rate (people recovering faster) has two main effects on the disease outbreak. First, people are removed from the infected group quickly because they have less time to transmit the disease and infect it to others. This causes the infection to peak at a lower percentage of the population. Second, the epidemic will burn out faster as aforementioned before the infected group are being depleted at a higher and faster rate. In reality, a high recovery rate is always better because it would lead to a less severe and shorter-lasting epidemic.

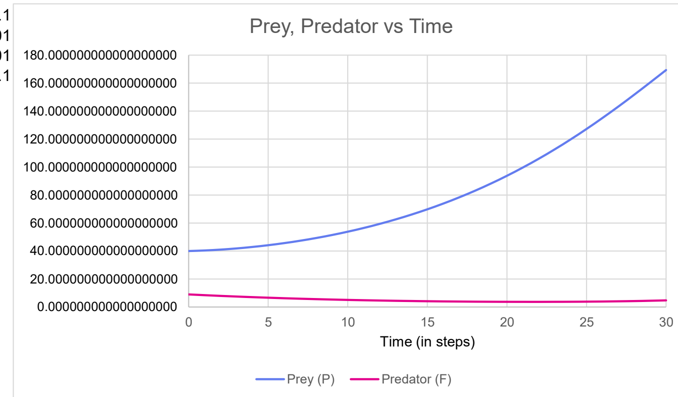
Why does infection eventually decline even without intervention?

Based on my research, the infection will decline without intervention because there is a depleition of susceptible people to infect (like how are you going to infect others if there is nothing to infect anymore?). The fuel of an epidemic is the susceptible population. The infection spreads when an infected person contacts and transmits the disease to the susceptible person. Furthermore, recovered people do not get reinfected and they get immune against the virus (based on this model only) which further reduce the transmission opportunities.

Predator–Prey Interaction (Lotka–Volterra Model)

Time (in steps)	Prey (P)	Predator (F)
0	40.000000000000000000	9.000000000000000000
1	40.400000000000000000	8.460000000000000000
2	41.022160000000000000	7.955784000000000000
3	41.860741558265600000	7.486569044173440000
4	42.912882394929600000	7.051305471672350000
5	44.178252210056600000	6.648766766941720000
6	45.658768479904300000	6.277620985363340000
7	47.358360896141800000	5.936487330002300000
8	49.282773891459800000	5.623980906431690000
9	51.439397486790100000	5.338748195170080000
10	53.837117330536800000	5.079495366146310000
11	56.486175183519100000	4.845011217538820000
12	59.398031177870900000	4.634186248184950000
13	62.585218903120500000	4.446029162620200000
14	66.061183709510100000	4.279681954750420000
15	69.840093522150700000	4.134434615106430000
16	73.936609872563200000	4.009740453776030000
17	78.365604703608800000	3.905233024019500000
18	83.141805699611800000	3.820745669053340000
19	88.279349329132300000	3.756334796192080000
20	93.791216345343400000	3.712308108243080000
21	99.688519050669800000	3.689259190339570000
22	105.979603104946000000	3.688110056384640000
23	112.668919015611000000	3.710163490729180000
24	119.755609818456000000	3.757167251527910000
25	127.231752246335000000	3.831392381771770000
26	135.080179808207000000	3.935727909870680000
27	143.271809451613000000	4.073793952625120000
28	151.762392087518000000	4.250074388288250000
29	160.488616739105000000	4.470068405175940000
30	169.363527462256000000	4.740456659734210000

r	0.1
a	0.01
b	0.001
d	0.1



Guide Questions:

What happens if there are too many predators?

If there are too many predators, the prey population will decrease since they cannot reproduce quickly due to being overhunted. The predators will eventually run out of food as the prey becomes fewer and their population will decline due to starvation.

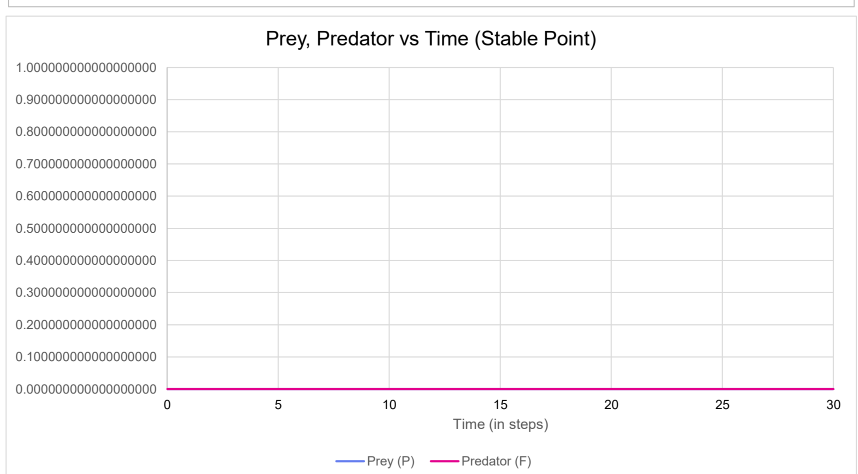
What pattern do you observe between prey and predator cycles?

Based on the model simulated, the pattern observed is a continuous cycle of oscillation where the predator population lags behind the prey population. This means several reasons. First, the prey population increases first as seen from t = 1 to t = 30. This growing food source then allows the predator to start increasing as well as seen from t = 26 onwards. If we will add more 5 days from the simulation, the increase of predator will be apparent. As aforementioned before, the predators will eventually become numerous enough to cause the prey population to also decline, which in turn will cause the predator population to dcline due to lack of food, starting the cycle over again.

Time (in steps)	Prey (P)	Predator (F)
0	0.000000000000000000	0.000000000000000000
1	0.000000000000000000	0.000000000000000000
2	0.000000000000000000	0.000000000000000000
3	0.000000000000000000	0.000000000000000000
4	0.000000000000000000	0.000000000000000000
5	0.000000000000000000	0.000000000000000000
6	0.000000000000000000	0.000000000000000000
7	0.000000000000000000	0.000000000000000000
8	0.000000000000000000	0.000000000000000000
9	0.000000000000000000	0.000000000000000000
10	0.000000000000000000	0.000000000000000000
11	0.000000000000000000	0.000000000000000000
12	0.000000000000000000	0.000000000000000000
13	0.000000000000000000	0.000000000000000000
14	0.000000000000000000	0.000000000000000000
15	0.000000000000000000	0.000000000000000000
16	0.000000000000000000	0.000000000000000000
17	0.000000000000000000	0.000000000000000000
18	0.000000000000000000	0.000000000000000000
19	0.000000000000000000	0.000000000000000000
20	0.000000000000000000	0.000000000000000000
21	0.000000000000000000	0.000000000000000000
22	0.000000000000000000	0.000000000000000000
23	0.000000000000000000	0.000000000000000000
24	0.000000000000000000	0.000000000000000000
25	0.000000000000000000	0.000000000000000000
26	0.000000000000000000	0.000000000000000000
27	0.000000000000000000	0.000000000000000000
28	0.000000000000000000	0.000000000000000000
29	0.000000000000000000	0.000000000000000000
30	0.000000000000000000	0.000000000000000000

Stable Point (P = 0, F = 0)

Assuming the trivial equilibrium, where both prey and predator populations are 0, results in 0 = 0. Since neither species exists, there are no interactions or changes in population. Therefore, this point is considered stable because the system remains constant over tim



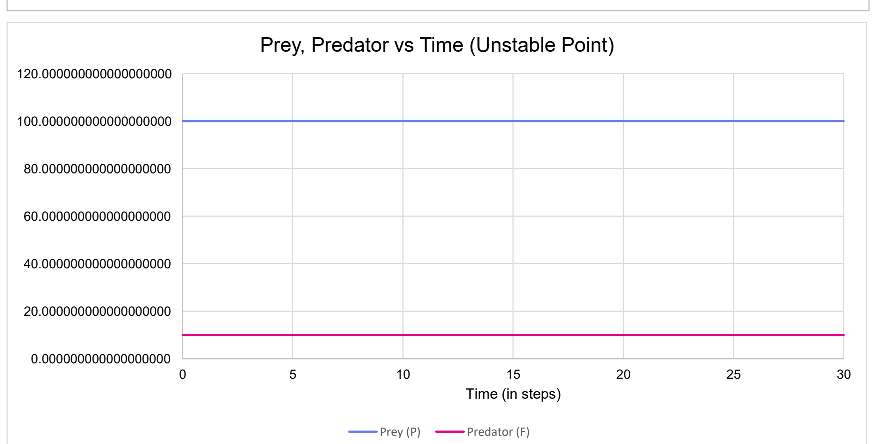
Time (in steps)	Prey (P)	Predator (F)
0	100.000000000000000000	10.000000000000000000
1	100.000000000000000000	10.000000000000000000
2	100.000000000000000000	10.000000000000000000
3	100.000000000000000000	10.000000000000000000
4	100.000000000000000000	10.000000000000000000
5	100.000000000000000000	10.000000000000000000
6	100.000000000000000000	10.000000000000000000
7	100.000000000000000000	10.000000000000000000
8	100.000000000000000000	10.000000000000000000
9	100.000000000000000000	10.000000000000000000
10	100.000000000000000000	10.000000000000000000
11	100.000000000000000000	10.000000000000000000
12	100.000000000000000000	10.000000000000000000
13	100.000000000000000000	10.000000000000000000
14	100.000000000000000000	10.000000000000000000
15	100.000000000000000000	10.000000000000000000
16	100.000000000000000000	10.000000000000000000
17	100.000000000000000000	10.000000000000000000
18	100.000000000000000000	10.000000000000000000
19	100.000000000000000000	10.000000000000000000
20	100.000000000000000000	10.000000000000000000
21	100.000000000000000000	10.000000000000000000
22	100.000000000000000000	10.000000000000000000
23	100.000000000000000000	10.000000000000000000
24	100.000000000000000000	10.000000000000000000
25	100.000000000000000000	10.000000000000000000
26	100.000000000000000000	10.000000000000000000
27	100.000000000000000000	10.000000000000000000
28	100.000000000000000000	10.000000000000000000
29	100.000000000000000000	10.000000000000000000
30	100.000000000000000000	10.000000000000000000

Unstable Point (P = 100, F = 10)

For Predators to be stable (Ft+1 = Ft):
b*Pt*Ft - d*Ft = 0
b*Pt*Ft = d*Ft
b*Pt = d
Pt = d / b
P = 0.1 / 0.001 = 100

For Prey to be stable (Pt+1 = Pt):
r*Pt - a*Pt*Ft = 0
r*Pt = a*Pt*Ft
r = a*Ft
Ft = r / a
F = 0.1 / 0.01 = 10

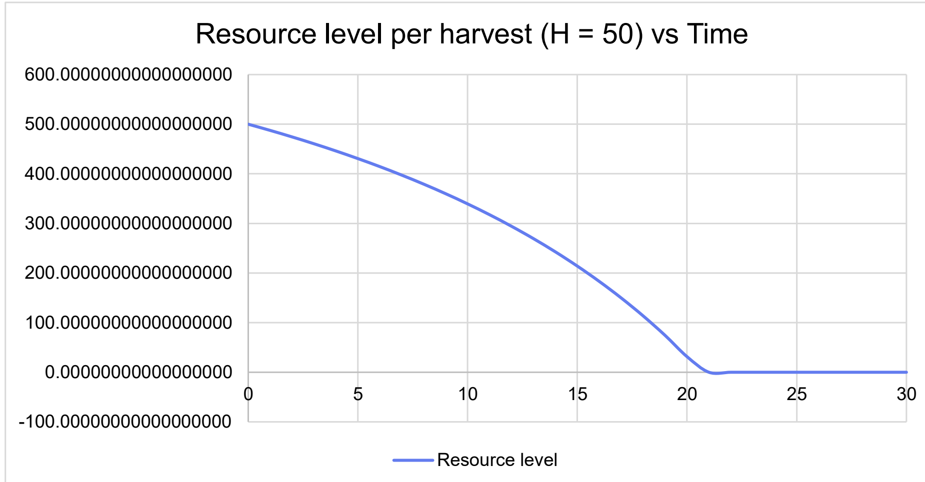
Assuming the coexistence equilibrium, where the prey population is 100 and the predator population is 10, both species can survive and interact. This point is neutrally stable, meaning the populations oscillate around this balance without permanently increasing or decreasing.



Resource Depletion and Regeneration

Time (in steps)	Resource level
0	500.00000000000000000
1	487.50000000000000000
2	474.36718750000000000
3	460.55269482116700000
4	446.00252506793200000
5	430.65686495637600000
6	414.44928468531100000
7	397.30580267503400000
8	379.14378790057500000
9	359.87066609545300000
10	339.38238788919900000
11	317.56160641765000000
12	294.27549836588700000
13	269.37314475555100000
14	242.68236467533100000
15	214.00586463664400000
16	183.11652559536400000
17	149.75159505759500000
18	113.60547755224000000
19	74.32071508097000000
20	31.47660815455970000
21	0.00000000000000000
22	0.00000000000000000
23	0.00000000000000000
24	0.00000000000000000
25	0.00000000000000000
26	0.00000000000000000
27	0.00000000000000000
28	0.00000000000000000
29	0.00000000000000000
30	0.00000000000000000

K	2000
r	0.1
H	50



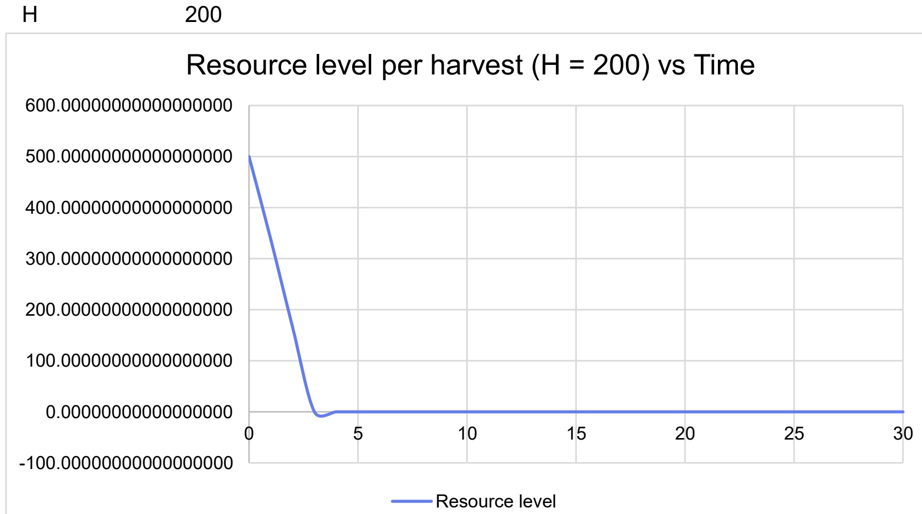
Guide Questions:

At what harvest rate does the population collapse?
In the given simulation, the population collapses at t = 21 when the harvest rate of H = 50 and t = 3 when the harvest rate is 200. Both harvest rates are higher than the population's natural regeneration rate of merely 0.1. A population collapses when what is being taken out (harvest rate) is more than what's being added (regeneration rate).

How can such a model help in sustainable fishing?
This particular model is a critical tool for predicting the long-term haelth of a fish population as it helps setting sustainable quotas and simulating policy consequences. For setting sustainable quotas, the model can be used to find the maximum sustainable yield by which the harvest rate is equal to the regeneration rate. This allows authorities to set fishing quotas that prevents the fish population from collapsing ensuring a stable food source and long-term industry. For simulating policy consequences, the model can act as an early warning system and allows policymakers and scientists simulate different scenarios to see future consequences of their decisions before they cause a real-world fish population destruction.

Time (in steps)	Resource level
0	500.00000000000000000
1	337.50000000000000000
2	165.55468750000000000
3	0.00000000000000000
4	0.00000000000000000
5	0.00000000000000000
6	0.00000000000000000
7	0.00000000000000000
8	0.00000000000000000
9	0.00000000000000000
10	0.00000000000000000
11	0.00000000000000000
12	0.00000000000000000
13	0.00000000000000000
14	0.00000000000000000
15	0.00000000000000000
16	0.00000000000000000
17	0.00000000000000000
18	0.00000000000000000
19	0.00000000000000000
20	0.00000000000000000
21	0.00000000000000000
22	0.00000000000000000
23	0.00000000000000000
24	0.00000000000000000
25	0.00000000000000000
26	0.00000000000000000
27	0.00000000000000000
28	0.00000000000000000
29	0.00000000000000000
30	0.00000000000000000

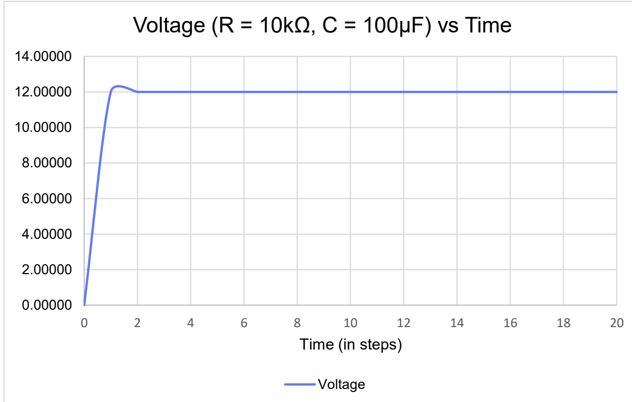
H	200



Charging a Capacitor (RC Circuit Model)

Time (in steps)	Voltage
0	0.00000
1	12.00000
2	12.00000
3	12.00000
4	12.00000
5	12.00000
6	12.00000
7	12.00000
8	12.00000
9	12.00000
10	12.00000
11	12.00000
12	12.00000
13	12.00000
14	12.00000
15	12.00000
16	12.00000
17	12.00000
18	12.00000
19	12.00000
20	12.00000

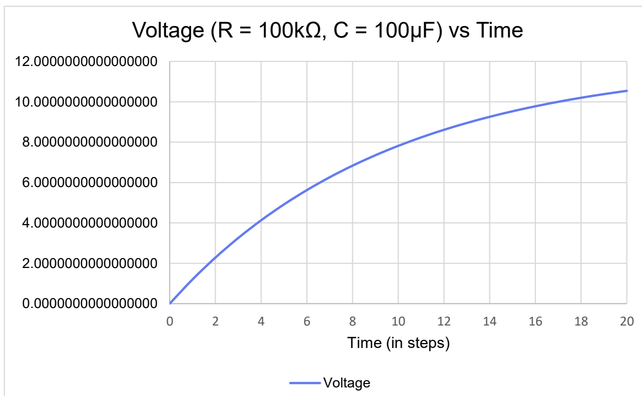
Vmax	12
R	10000
C	0.0001



Change R or C - how does it affect the charging time?
Yes, it does affect the charging time. In the first simulation, this effect is dramatic. Although t = 1 to t = 20 are constantly 12V, there is a rapid and instantaneous change from t = 0 to t = 1 wherein voltage jumps from 0V to 12V. This is because the values of R and C gives a constant of 1 which makes the capacitor charge instantly hitting exactly 12 V in the first time step. The change of R or C (or both) significantly affects the charging time, as seen in simulations 2, 3, and 4. Increasing either R or C resulted in a much slower, more gradual charge.

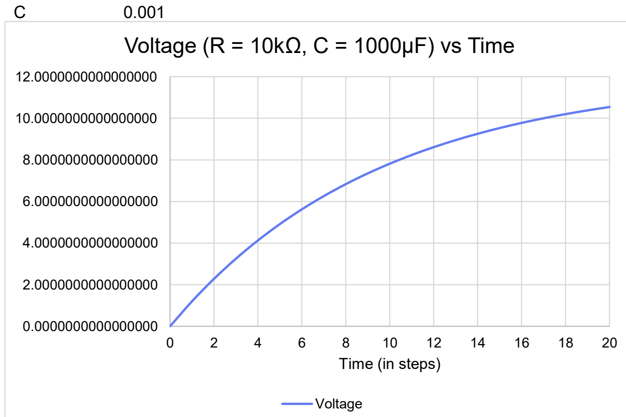
Time (in steps)	Voltage
0	0.0000000000000000
1	1.2000000000000000
2	2.2800000000000000
3	3.2520000000000000
4	4.1268000000000000
5	4.9141200000000000
6	5.6227080000000000
7	6.2604372000000000
8	6.8343934800000000
9	7.3509541320000000
10	7.8158587188000000
11	8.2342728469200000
12	8.6108455622280000
13	8.9497610060052000
14	9.2547849054046800
15	9.5293064148642100
16	9.7763757733777900
17	9.9987381960400100
18	10.1988643764360000
19	10.3789779387924000
20	10.5410801449132000

Vmax	12
R	100000
C	0.0001



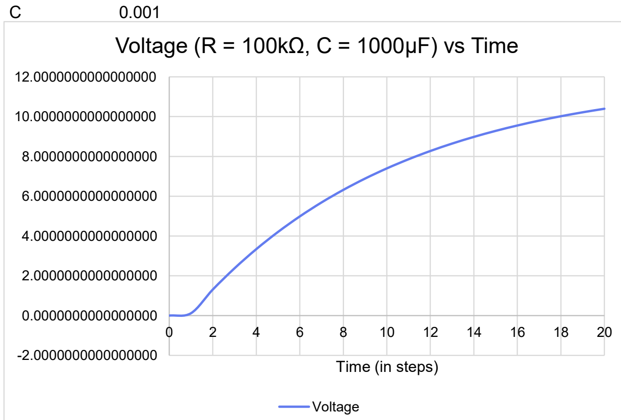
Time (in steps)	Voltage
0	0.0000000000000000
1	1.2000000000000000
2	2.2800000000000000
3	3.2520000000000000
4	4.1268000000000000
5	4.9141200000000000
6	5.6227080000000000
7	6.2604372000000000
8	6.8343934800000000
9	7.3509541320000000
10	7.8158587188000000
11	8.2342728469200000
12	8.6108455622280000
13	8.9497610060052000
14	9.2547849054046800
15	9.5293064148642100
16	9.7763757733777900
17	9.9987381960400100
18	10.1988643764360000
19	10.3789779387924000
20	10.5410801449132000

Vmax	12
R	10000
C	0.001



Time (in steps)	Voltage
0	0.0000000000000000
1	0.1200000000000000
2	1.3080000000000000
3	2.3772000000000000
4	3.3394800000000000
5	4.2055320000000000
6	4.9849788000000000
7	5.6864809200000000
8	6.3178328280000000
9	6.8860495452000000
10	7.3974445906800000
11	7.8577001316120000
12	8.2719301184508000
13	8.6447371066057200
14	8.9802633959451500
15	9.2822370563506300
16	9.5540133507155700
17	9.7986120156440100
18	10.0187508140796000
19	10.2168757326717000
20	10.3951881594045000

Vmax	12
R	100000
C	0.001



Guide Questions:
Does the voltage ever reach exactly 12V?
Based on the first and original simulation, yes it did reach 12V if only R = 10k Ω and C = 100µF because the RC constants equals to 1. In other simulations, where R or C was larger (simulations 2 and 3), the voltage gets closer and closer but never actually reach es 12V, it just approaches it (wherein the last time step voltage was around 10V.

What is the physical meaning of a larger time constant (RC)?
The physical meaning of a larger constant (RC) is that the capacitor charges more slowly. A larger R (resistance) restricts the flow of electric current whereas a larger C (capacitance) means it takes more time and charge to fill up to the same voltage level. B oth of these factors (larger R or C) increases the RC value which significantly affects and directly corresponds to a longer and more grad ual charging time as seen in simulations 2, 3, and 4

Reflection Questions

What trend or pattern did you notice in your simulation?

Spread of Infectious Disease Model - The simulation showed a clear progression of an epidemic. The Susceptible population steadily decreased as the Infected population increased with a peak value (approximately 0.4268 or 42.68%) and then declined. Meanwhile, the Recovered population consistently increased which become the largest group at day 40.

Predator-Prey Interaction (Lotka-Volterra Model) - The model demonstrated a continuous oscillating cycle, meaning the populations fluctuate up and down in a repeating pattern. The prey, starting with an initial population of 40, increased first. This growing food source eventually allowed the predator population to grow as well, lagging behind the prey's peak. At first, the predators (starting at 9) were decreasing, but then at some point, their population began to increase again, confirming this continuous oscillating cycle. While this specific simulation shows a stable cycle, in such models, even slight parameter changes can break this pattern, causing populations to either converge to a stable point or diverge toward collapse.

Resource Depletion and Regeneration Model - If the harvest rate is greater than the regeneration rate then there will be a rapid resource population decline. In order for the harvest rate to be sustainable, it needs to reconsider the regeneration rate of the resource; specifically, the model can be used to find the maximum sustainable yield by determinining the point at which the harvest rate equals the regeneration rate.

RC Circuit Model - The trend was an asymptomatic charge. For the first and original simulation, the voltage started at 0 and increased at the maximum voltage given and maintained it for the rest of the time in steps. As for the other simulations wherein R or C was increased, there was a gradual increase for the voltage wherein it approaches approximately to the maximum voltage given

How did changing parameters affect system behavior?

Changing parameters have significant influence and directly effects the outcomes of each simulation models. For instance,

Spread of Infectious Disease Model - Increasing the recovery rate would have two main effects to the simulation wherein the infection would peak at a lower percentage and the epidemic would end more quickly since most people are immune and there is less susceptible people to infect.

Resource Depletion and Regeneration Model - Evident in showing affecting outcomes. When the harvest rate was increased to 200 the resource population depleted instantaneously when t = 3. This shows that the model is highly sensitive to parameter changes especially in harvest rate.

RC Circuit Model - In the capacitor model, changing the resistance and capacitor directly can impact the charging time. The initial simulation caused an instantaneous change by jumping from 0V to 12V. However, it is more apparent when the resistance and capacitor value wherein each of them were increased and both increased which shows a slower and gradual charge. A larger resistance restricts the electric current flow while a larger capacitance requires more charge to fill which both lengthen the charging time which explains why the trend for these simulations were asymptomatic to the maximum voltage given.

Did the system reach equilibrium, oscillate, or diverge?

Spread of Infectious Disease Model - Showed reaching equilibrium as the number of infected individuals peaked at day 21 and then declined approachingly to zero. The susceptible and recovered populations stablized at new and constant levels as the epidemics burned out.

Predator-Prey (Lotka-Volterra Model) - Showed oscillations wherein the population cycles continuously. This is particularly evident in the coexistence equilibrium wherein the prey should be 100 and predators should be 10 which makes the system neutrally stable with populations oscillating around this balance.

Resource Depletion Model - Showed divergence to a state of collapse. The resource level was driven to zero and did not even reached the time steps given when the harvest rate was set to 50 and 200 as they were higher than the population's natural regeneration rate leading to a stable but depleted equilibrium of 0.

RC Circuit Model - Showed equilibrium on the first simulation wherein it started at 0V and instantaneously jumped to 12V. Other simulations also showed a gradual and asymptomatic charge to the maximum voltage given.

What assumptions in your model might not hold true in reality?

SIR Model - This model assumes that the recovered individuals gain permanent immunity and cannot be reinfected when in reality immunity for many diseases can wane over time. The model also assumes that the fuel for the epidemic are existing susceptible people and did not take account new births.

Predator-Prey (Lotka-Volterra Model) - This model assumes that the predator population's survival is only tied to a single prey psecies and the prey's only threat is a single predator. In reality, predators can have multiple food sources and prey also faces other dangers like disease and competition.

Resource Depletion and Regeneration Model - This model assumes that harvest rate is normal regardless of how scarce the resource becomes. In real world fishing scenario, a lower resource population makes fishing less efficient or profitable which causes decline in harvest rate and affecting the socioeconomic status of fishermen.

RC Circuit Model - This first simulation showed an instantaneous jump from 0V to 12V in a single time step which is too idealistic and does not consider physical reality. A real circuit cannot charge instantaneously.