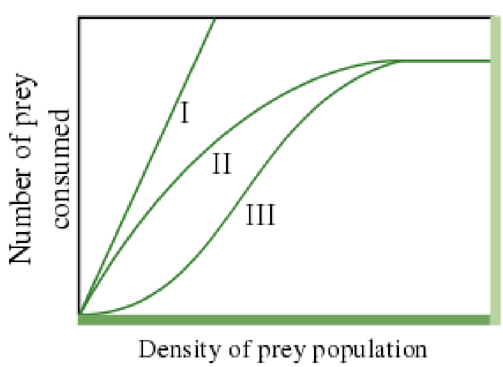
```
import numpy as np
import matplotlib.pyplot as plt
import scipy.integrate as integrate
import math

def main():
    global grouper_harv
    global lion_attack

    C0 = 212
    L0 = 45
    G0 = 178

    K = 800
    RC = .447
    dl = .3
    bl = .05
    grouper_harv = .349
    lion_attack = 8.6/240

    t = np.linspace(0, 5, num=300)
    y0 = [C0, L0, G0]

    y = integrate.odeint(derivs, y0, t, args=(dl,RC,K,bl))
```

- **grouper_harv, lion_attack**
  - Two global constant terms so that they don't need to be passed to the integrator(for simplicity) and for understandability.
- **C0, L0, G0**
  - Initial conditions. L0,C0 are the only two used in all graphs but the last graph
- **K,RC,dl,bl**
  - Terms well defined already in the model
- **t**
  - The time variable which is an array populated with **np.linspace(** *start, stop, steps* **)** .
    - **linspace()** is a method of *numpy* (called *np* here)
    - The array has roughly $(stop - start)steps$ number of elements
- **y0**
  - Array of initial conditions. Required by 2-D DE solver
- **y**
  - 2-D array that stores the returned values from the differential system
  - Calls function **integrate.odeint(***function, initial conditions, time-space, arguments)***)**

    * **integrate** is a class of the package *scipy*.
    * **odeint()** is a method of **integrate** and is the DE solver.

```
def derivs(state,t,dl,RC, K,bl):
    global lion_attack, grouper_harv

    C, L ,G = state

    g= C*RC - C*RC*C/K - L*(C*lion_attack)/(1+C*lion_attack*.4)

    f= L*((bl*lion_attack*C) - dl) -  (L*(2*G)/(1+.91*G))

    h = (G*(.8) - G*.8*G/3000)


    return g, f,h
```

- **derivs**
  - Python Function called at each time-step in **t**
- **state**
  - Array that serves the same purpose as **y0**, but is continually updated as **derivs** is called.
    * Array values are assigned to C, L, and G respectively.
- **g**
  - The variable that stores the value of **g** at time **t**
    * **g** is representative of the $\frac{dC}{dt}$.
    * $C * RC - C * RC * C/K$ is the logistic portion of the model.
    * $(C * lion\_attack)/(1 + C * lion\_attack * .4)$ is the functional response type II which, based on density, gives the number of grams of coral-fish removed by lionfish per time-step. Once multiplied by L, it gives us the total number of coral-fish removed over the area per time-step/
    * This graphic, from $http : //en.wikipedia.org/wiki/Functional\_response$, you can see that, with functional response type II, the number of prey consumed decreases nonlinearly as prey density decreases.



- **f**
  - The variable that stores the value of **g** at time **t**
    - **f** is representative of the $\frac{dL}{dt}$.
    - $(bl * lion\_attack * C) - dl$ is the numerical response function that models the lion-fish growth rate based on the consumption of coral-fish and some energy conversion rate **bl**.
    - $((2 * G)/(1 + .91 * G))$ as with **g**, this is a very modified functional response type II for the number of lion-fish removed once multiplied by L [*Only used in last final figure*]
- **h**
  - The variable that stores the value of **g** at time **t**
    - **f** is representative of the $\frac{dG}{dt}$.
    - $G * .8 - G * .8 * G/3000$ is a simple logistic growth model for the population of grouper. [*Note: Only used in final figure*]

Why we did what we did.

figure1
The first figure we used showed the behavior of the coral-fish population. As $t \to \infty$ the population density moves toward K, smoothly and nicely. That smooth, non-periodicity is what we'd like from our solution to the lion-fish problem

figure2,3,4
These show the severity of the problem of the lionfish, and how they really destabilize the coral-fish population. The fourth figure show our assumed current natural conditions.

figure5,6,6b,7,8
These figures show the introduction of grouper and most importantly figure8 shows that we can get the behavior of the coral-fish population growth to return to the behavior of figure1, even if it's at a reduced capacity.

figure9,10,11,12,12b
We modify the $h_{L,G}$, decreasing it until we find that minimum threshold ($h_{L,G} > .35$) by which we get the desired population growth behavior of coral-fish