Proposal for Modeling of potential control measures for the Lionfish invasion in USVI

MATH 452

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I. Introduction

This is a proposal to model the invasive lionfish species as a function of coral fish, grouper, and humans. Lionfish, a beautiful but deadly fish native to the Indo-Pacific region, are previously only found in fish tanks. Due to releasing lionfish by residents in South Florida they have invaded much of the Caribbean including the US Virgin Islands. The lionfish invasion has been considered the worst environmental disaster the Atlantic will ever face. With few natural predators and extremely high reproductive rates they are decimating the populations of coral fish. Due to this real life concern this project will model the system and analyze different methods of lionfish removal.

Initially the model with include a human and grouper harvesting rate of lionfish. With this additional differential equations that model the population and interaction of the grouper with the system will be studied.

As adding a new species into a system introduces an entirely new set of problems, these will be addressed and the potential effects and solutions studied. This research will attempt to present the lionfish, grouper, and coral fish populations, time, cost, effects on tourism, and environmental effects as major considerations for effective solution.

II. Questions / Goals

(a) What is the critical harvesting rate of lionfish in USVI to drive the population towards extinction by means of Human harvesting, other aquatic harvesting such as grouper, or both?

(b) What environmental issues may arise by introducing other species such as grouper to the population?

(c) What is the time and cost of different possible solutions?

(d) What is the economic impact on tourism in different scenarios?

III. Preliminary Model

Taking into account the lionfish, grouper, coral fish, and humans there are several ways of constructing the model. Possible different scenarios considered for modeling were: two predators with a common prey, a prey whose predator is the prey of a higher-level predator, two species in competition and a third species that is the prey of one of them, and two species in competition and a third species that is a predator of one of them. For simplicity the human

population is taken to be a constant the model is of the three aquatic species. The model is based off of the Lotka-Voltera Model for predator-prey with a second predator added. The following model is constructed with both the lionfish and grouper being predators of the coral fish while prey of humans and the lionfish is also a prey of the gouper:

$$\frac{dL}{dt} = (Cb_L - d_L)L - h_{(L,G)}LG - h_{(L,H)}L$$

$$\frac{dG}{dt} = ((C + L)b_G - d_g)G - h_{(G,H)}G$$

$$\frac{dC}{dt} = (b_C - d_C)C - h_{(C,L)}CL - h_{(C,G)}CG$$

Variables:

C	Biomass of Coral Fish
L	Biomass of Lionfish
G	Biomass of Grouper
b_C, d_C	Reproductive and death rate for Coral Fish (b for birth, d for death)
b_L, d_L	Reproductive and death rate for Lionfish (b for birth, d for death) (*)
b_G, d_G	Reproductive and death rate for Grouper (b for birth, d for death) (*)
$h_{(X,Y)}$	Density dependent harvesting rate of X by Y (**)

(a) (*) b_L & b_G are more specifically a rate by which groupers and lionfish convert their prey into new offspring. This is considered so that if the lionfish eat all the coral fish then the lionfish population decreases to extinction. For the grouper, that conversion rate is written as such because not only do groupers eat lionfish, but they have also been observed to eat coral fish (though supposedly at a lesser rate).

(b) (**) The focus of this study is only in USVI. As given population size decreases, the interactions between that species and others, and thus the chance of predation occurring, decreases.

IV. **Outline approach to address questions**

(a) Data collection.

   i. Use USGS website to get lionfish invasion in USVI information such as the current population and harvesting rate by humans.

   ii. Find all relevant data regarding the reproductive rates of lionfish, Caribbean grouper, and coral fish in USVI from published documents and online resources.

   iii. Literature review on predator-prey models with multiple predators.

   iv. Review potential for other aquatic predators of the lionfish to be introduced.

(b) Time and financial considerations.

   i. Different approaches and external costs must be considered for different solutions to all scenarios. The potential impact of the following must be presented with results.

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A. The current rate humans harvest lionfish may be the most cost effective but even if this is increased the time line for removal of lionfish may be unrealistically long.

B. Introducing a grouper population may quickly remove or reduce the lionfish population but the aquaculture expenses involved in stocking the USVI with grouper might be overwhelming.

C. Options and expenses to remove the grouper after the lionfish would also need to be considered.