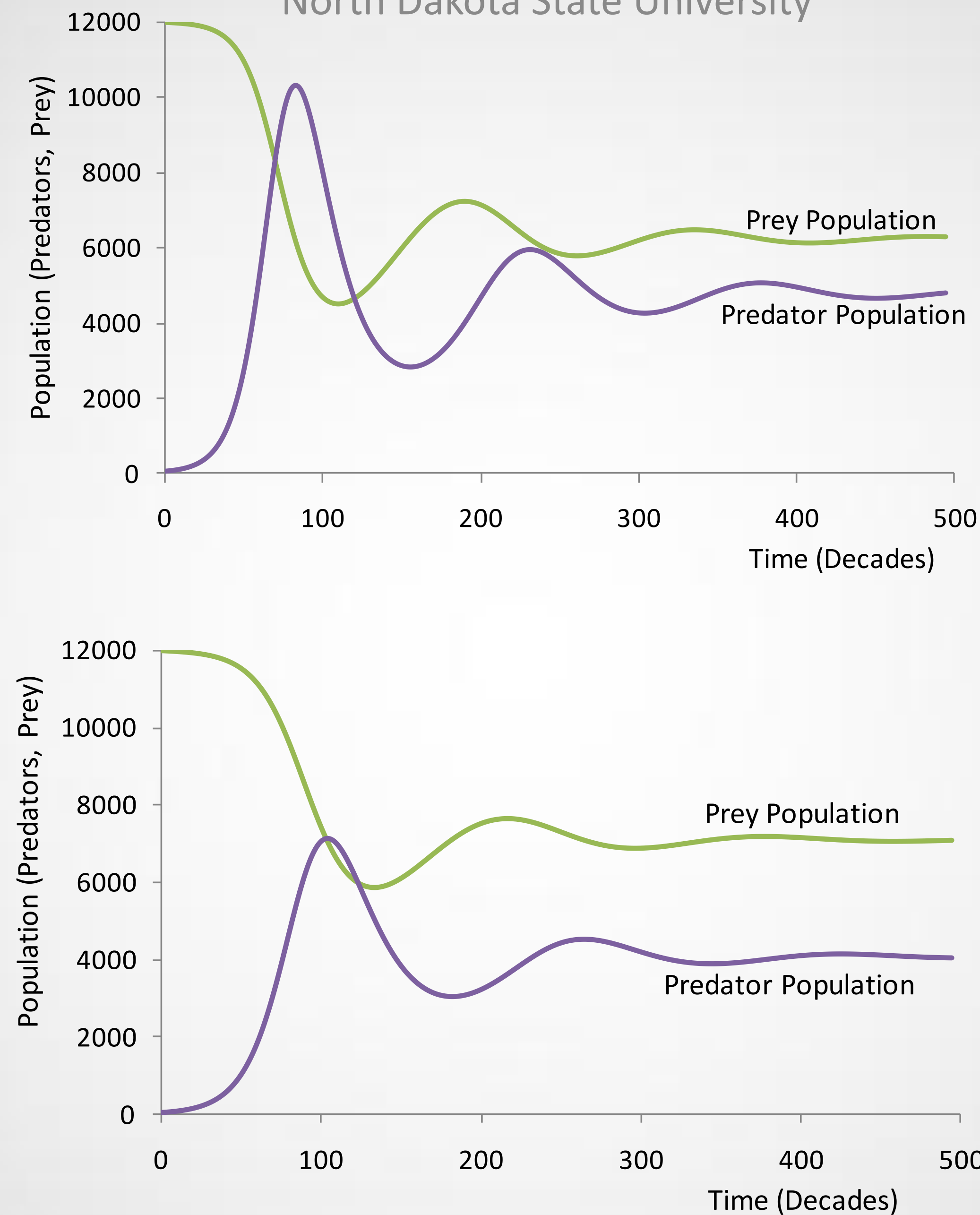


# Biological, Technological, and Economic Relationships between

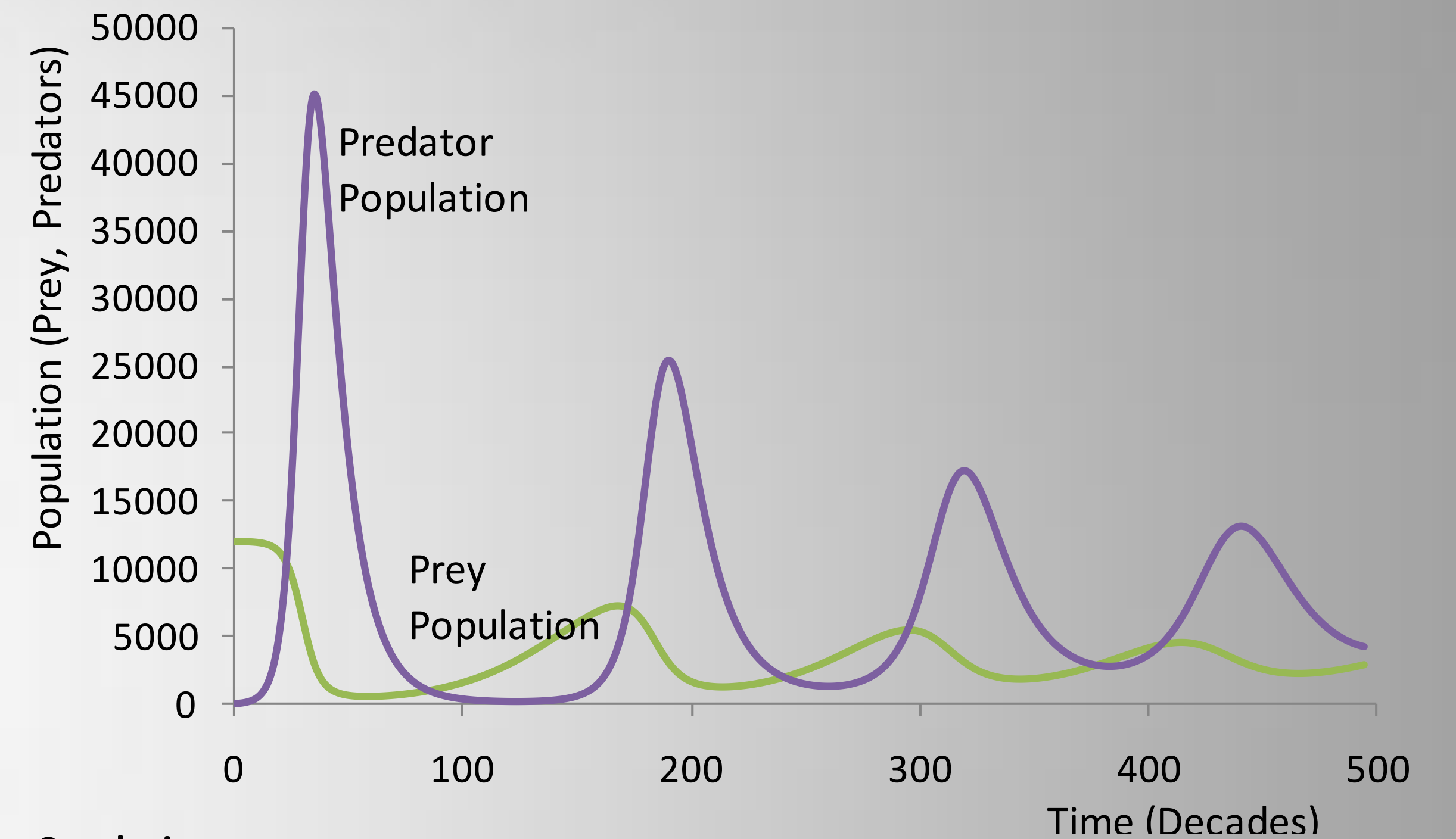
## Predator and Prey

David C. Roberts, Assistant Professor,  
North Dakota State University



### Results

Because improvements in extractive efficiency and use-efficiency have the effect of reducing the price of useful output from the resource sector, it is determined that both types of technological advancement will ultimately increase the demand for the resource good through population growth, unless the fertility function decreases sufficiently as real income levels rise. Without a sufficient decrease in fertility rates, population collapse and reduced standards of living may be inevitable.



### Conclusions

Improved resource use efficiency does not automatically counteract increased extractive efficiency in terms of taking pressure off a natural resource base. In fact, technological advancement may put increasing pressure on natural resources unless fertility decreases sufficiently to counteract the forces of technological change.

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### Introduction

Brander and Taylor (1998) developed a bioeconomic model to describe the dynamics of a Lotka-Volterra predator-prey system when the prey is an open-access resource. They apply their model specifically to explain the rapid rise and collapse of human civilization on Easter Island. They propose that socio-economic collapse was caused by unsustainable harvest—and eventual extinction—of the palm trees essential to the economic prosperity of ancient Easter Islanders. Elimination of this resource reduced the carrying capacity of the island and standard of living for the remaining inhabitants because other forms of natural capital, such as reeds and bushes, were only weakly substitutable for palm trees in the production of shelter and fishing vessels. Brander and Taylor (1998) clearly illustrate the forces that lead to market failure in the presence of open-access resources, and discover the set of starting parameters that could lead to stable equilibrium populations of both predator and prey. However, they assume no change in predatory efficiency over time.

Coevolution—the process by which predator and prey species adapt responsively through natural selection—has the tendency to keep predator and prey populations at stable equilibrium levels, assuming sufficient numbers of susceptible and unsusceptible prey upon the introduction of a new predator (Saloneimi, 1993). However, it is possible that all potential prey animals would be susceptible to predation by a novel predator. For example, the introduction of rats to Pacific islands has led to the extinction of several seabird species (Jones et al., 2007). The biological fitness of the introduced predator relative to a prey species may be what leads introduced species to become "invasive."

The global spread of humans is partially due to biological and technological innovations, such as weapons for hunting large game and technologies for efficient extraction of marine resources. Advanced technology allows humans to inhabit virtually any climate and exploit any useful resource. Human predation has led to the extinction of Steller's sea cow, the great auk and others (Vermeij, 1992). Currently, many high valued fish stocks have drastically declined due to over-fishing (Fromentin and Powers, 2005; Rose, 2004).

This research assumes two types of technological innovations exist: 1) those that improve extractive efficiency, and 2) those that improve use-efficiency.

### Objectives

1. To describe the effects of technological and biological fitness of predators relative to prey on the population dynamics of the bioeconomic system.
2. To determine the effects of technological innovation on the long-run success of potentially invasive species

### Methods

The model used is based on Brander and Taylor (1998). However, we assume that harvested units of the resource based do not directly satisfy the wants of the predator, but are transformed into consumption goods through some technological process. The model is as follows:

$$\frac{dV}{dt} = [r(1 - V/K) - \tau\beta]V$$

$$\frac{dL}{dt} = [\rho\theta\tau\beta V - d]L$$

$V$  = population of the prey resource  
 $K$  = carrying capacity of the prey resource  
 $r$  = prey population growth rate  
 $\tau$  = extractive efficiency  
 $\beta$  = utility function parameter  
 $\rho$  = fertility function  
 $\theta$  = use efficiency  
 $d$  = predator death rate, absent useful output