Q2: Hysteresis and Management

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# Abstract

# Introduction

The relationship between hysteresis and fisheries

Ecosystem-based management  
What Ecosystem-based management/adpative management is.  
Shown to increase system resilience  
ecosystem-based management has been shown to increase resilience of systems (Hansen et al. 2015). May be useful in systems where linear management is not effective (Pine et al. 2009).  
Managing systems that are subject to regime shifts - magnitude of management response matters (Biggs, Carpenter, and Brock 2009)

Cultivation and Depensation.  
Some species may be able to cultivate ideal conditions for themselves by having competitive advantage or consuming juveniles of other species (Walters and Kitchell 2001).  
Depensatory processes can occur when fishing reduces the adult population (Walters and Kitchell 2001).  
How much do we want to focus on cultivation-depensation?

Recreational angling has a major impact on the ecology of freshwater ecosystems and is likely to structure community dynamics through selective harvest of certain individuals and species from the system **(citation)**. In recognition of the impact anglers have on freshwater fish communities, ecosystem-based management, adaptive management, and safe operating spaces have all been invoked in an effort to better manage freshwater resources. A central theme of these strategies is a holistic view of the ecosystems we manage and a rejection of single species management strategies applied broadly in favor of flexibility that allows managers to consider the full context of the systems they work in and tailor their actions appropriately. Current work to incorporate ecosystem-based management has focused on ecosystem change, such as climate change, and management strategies to maintain stable states of a system in light of ecosystem change(**???**).However, some work has been done which focuses on other potential drivers of regime shifts. One drive of particular interest in fisheries is potential for harvest driven regime shifts(Steele 1996),(Rothschild and Shannon 2004).

Harvest driven regime shifts in fisheries have been studied in commercial and marine fisheries when ecosystem-based management has been used (Oken and Essington 2016),(Essington et al. 2015). The recognition of the role interspecific interaction between species of commercial importance, and the hysteretic behavior that follows, has helped foster the adoption of ecosystem-based management. Crowder et al. (2008) has explored the simultaneous impacts of multiple fished species on marine systems. This type of ecosystem-based management plays an import role in maintaining a desired stable state, often in the form of a specific fish community structure. In freshwater systems however, there has been limited focus on the harvest of multiple interacting species and the consequences it has for maintaining a desire stable state in the system. The hysteretic behaviors of many freshwater communities have, to date, focused on models with a single harvested species while in reality most freshwater systems are home to multiple harvested fish species which often interact with each other.

Where the literature is at with hysteresis and management:  
Commercial fisheries  
-hysteresis and regime shift are important considerations in adaptive management in these systems (Steele 1996),(Rothschild and Shannon 2004).  
- Ecosystem-based management plays an important role in maintaining desired stable-state (Levin and Möllmann 2015).  
- Efforts to model this in multiple marine fishes (Crowder et al. 2008)  
- Management has been shown to manage desired stable states of coral reef areas (Blackwood, Hastings, and Mumby 2012)  
This model is unique in that it looks at hysteresis and management in (1) a freshwater system, and (2) a multispecies system in which both species are game fish.  
This model  
The goal of this study is:  
(1) to understand the role hysteresis plays in both the type and magnitude of management responses necessary to maintain a system in a desired configuration.  
(2) to investigate the role management responses can play in reverting to an alternative configuration.  
We do this by:  
Modeling species-specific responses to regulations and stocking  
Consideration of optimal strategy and magnitude to maintain system in a desire state  
With and without hysteresis  
Consideration of optimal strategy and magnitude to change system state.  
Also with and without hysteresis

# Methods

## The Model

Base model  
Stocking  
Management (species specific)  
How we got hysteresis in the system

## Simulation Space

### Figure to show basic model behavior

Optimal management scenarios

# Results

Responses to regulations and stocking (maintain system state)  
- optimal strategy and magnitude  
- influence of hysteresis

Responses to regulations and stocking (change system state)  
- optimal strategy and magnitude  
- influence of hysteresis

# Discussion

# References

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