Ecosystems are difficult to manage, aquatic systems and fisheries in particular, provide examples of this. Counterintuitive responses by fish populations to management have shown that in many cases a linear, single species focused view of these systems can lead managers to make decisions that, in hindsight, are ineffective or even detrimental to these systems. In some situations, the stable state of a system may shift to an undesirable state as a result of these actions, or an undesirable state may be reinforced despite well intentioned action by managers. The loss of ecosystem services due to the reinforcement of, or shift to, an undesirable stable state would clearly have a negative effect on society. Aquatic systems provide a myriad of benefits to society through ecosystem services that are both culturally and economically valuable.  **Then give examples of both.**

Examples of the causes and effects of ineffective management action on fisheries are reviewed in Pine et al. (2009). Here they use several case studies to explore why predictions for ecosystem response to a management action have been wrong in both simple and complex systems. A central theme of these incorrect predictions is a failure to consider interactions between multiple species and life stages in these systems. In aquatic communities, human impacts can directly affect multiple species at one time, and these species themselves may be in competition (**a non- fishery example here?**). Ultimately, through both direct effects and indirect effects cascading through the community, human disturbance in these systems is likely to affect all community members in various ways from direct harvesting of these species to changing environmental conditions leading to loss of habitat, food resources, etc. Human effects on slow moving, abiotic variables like climate will also alter community dynamics. This has been well described in aquatic communities (**eutrophication, lake browning, bass-walleye degree days**). Because of the varied ways in which humans impact these systems, and the numerous ways in which biotic life in these systems interact with each other, aquatic systems often behave in complex, non-linear ways.

Positive feedback loops can allow a stable state to reinforce itself such that efforts by managers to change the stable state may have no effects or unintended effects due to the complex interspecific interactions in the system. Walters and Kitchell (2001) describe how positive feedback loops can create two stable states in a food web consisting of a top predator and a forage species through cultivation-depensation effects. Under low exploitation the top predator species is abundant and able to cultivate conditions to increase survival of its juveniles by predating upon the predators of its juveniles, namely the forage species. Alternatively, a forage species may dominate when exploitation of the top predator is high (as is the case in many fisheries) allowing the forage species to cultivate conditions for itself through predation on juveniles. When abundance declines enough, recruitment of new juveniles to the population may actually decline through the process of depensation where there are so few spawning adults left that recruitment declines in spite of decreased intraspecific competition. The positive feedback loops that enable cultivation-depensation effects demonstrate one way in which aquatic systems may display non-linear dynamics. If the forage species has established itself as the dominant species, simply increasing the survival of adult predators may have no effect or possibly a negative effect if the associated increase in juvenile production further increases forage opportunities for the forage species and leads to further increases in their biomass with the increased prey availability. These dynamics allow the point at which the stable state changes to vary depending on which state the system is in. This hysteretic behavior can make rehabilitating ecosystems particularly difficult and costly. In fisheries, for example rehabilitating a collapsed fishery may not be accomplished simply through a reduction in fishing mortality past the point that caused the initial collapse. Instead drastic reductions in fishing mortality, coupled with stocking, and possibly habitat improvements may all be necessary to push the system out of its current stable state and back to the desired state.

The non-linearity that can arise when dealing with interspecific interactions as demonstrated by cultivation-depensation theory can lead to counterintuitive outcomes and can pose a problem for managers who are often limited in the options available to them (Carpenter et al. 2017). Carpenter et al. (2017) describe this situation where some things, like a changing climate, are outside the direct control of managers. Because of this, managers are only able to influence the system in certain ways based on the limited number of ‘levers’ they have control over. In light of this, Carpenter et al. (2017) lay out a conceptual framework where mangers aim to keep systems in a ‘safe operating space’ (SOS) using what they can control to compensate for forces outside their control while still achieving positive outcomes. In the case of recreational fisheries, the ‘levers’ available to managers are often based on linear, single species views of system dynamics (i.e. a reduction in harvest of species ‘X’ will result in a proportional increase in their population size). When the levers available to mangers, and the lens through which they view the system, do not consider interspecific interactions, regime shifts can occur that are likely to have major implications for both the ecology of the system and the human users of it (Xu et al. 2014). Regime shifts in coral reefs, due to increases in algae and coral bleaching, lead to reductions in fish biomass and a subsequent loss of food security and employment for the communities around these reefs (Norstrom et al. 2009, Crepin et al. 2012). The recognition of the role of interspecific and trophic interactions between species, and the hysteretic behavior that may follow, has helped foster the adoption of more ecosystem-based management strategies (Blackwood, Hastings, and Mumby 2012).

To date, much of the work thinking about stable states and ecosystem management has still focused on the management of a single species. In fisheries it is common to focus management related research is on a single focal species, even when this species is embedded in larger community where harvest of multiple species takes place (**citation**). The tradeoffs between competing management goals for several co-occurring species are often not considered, however some notable exceptions do exist (Essington et al. 2015, Oken et al. 2016, **others?**). Essington et al. (2015) uses competing objectives for a predator fishery (Atlantic cod, *Gadus morhua*) and a forage species fishery (Atlantic herring, *Clupea harengus*) to show how the ecological interactions between the two and the market price of each species combine to determine what the appropriate level of mortality on each species would be given the management goals (maximizing combined profit of both species at equilibrium. In contrast to commercial fisheries where users aim to maximize profit, recreational fishery users vary along multiple axes of species preference, catch rate, fish size, location, and harvest opportunity. Users place differing levels of importance on each of these aspects of the fishing experience. This can lead to divergent and in some cases, competing, desires by fishery users and ultimately complex management problems. Given the limited ways in which managers can influence recreational fisheries (i.e. fishing regulations, stocking, and habitat alterations), understanding and leveraging ecological interactions allows managers to make the most of the limited tools they have at their disposal to keep systems within a safe operating space and meet the diverse goals of users in this system.

Here we use an example of a fishery with two harvested species to explore how limited management levers and a linear, single species, system view can lead to counterintuitive responses by fish populations to management intervention. We then show how adopting a non-linear approach that considers community interactions can improve outcomes and help maintain a system in the desired stable state or safe operating space. In keeping with the idea that species do not occur in isolation and should not be managed that way, we choose the simplest fishery model possible while still allowing for the dynamics of multiple harvested species to occur. We use our model to explore how embracing the complexity of the system and leveraging ecological interactions can improve outcomes for a hypothetical recreational fishery. Our hypothesis that interspecific interactions play an important role in determining the appropriate management action leads us to predict that considering the non-linear dynamics arising from interspecific interaction leads to more positive outcomes for managers. Outcomes that are of specific interest here are economic benefits, high angler satisfaction, and a stable state where the desired species dominates.