Ecosystem-based management can be difficult to implement due to the nature of many ecosystems being nested within complex social-ecological systems. Aquatic systems, including fisheries, provide excellent examples to explore the difficulties of implementing ecosystem-based management. Although ecosystem-based management implementation may be difficult, it is nevertheless warranted. 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 (Hansen et al. 2015; Sass and Shaw 2020). 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 (Carpenter 2003; Carpenter et al. 2017). Aquatic systems provide a myriad of benefits to society through ecosystem services that are culturally and economically valuable; the loss of these ecosystem services due to the reinforcement of, or shift to, an undesirable stable state would likely have a negative effect on society. For example, human-induced eutrophication can result in **XX** (**CITATION**). Within fisheries, **XX** (**Citation).**

Several examples of the causes and effects of ineffective management action on fisheries were reviewed in Pine et al. (2009). Here, Pine et al. (2009) used several case studies to explore why predictions for ecosystem responses to management actions have been wrong in both simple and complex systems. A central theme of these incorrect predictions was a failure to consider interactions between multiple species and life stages. In aquatic communities, species may be in competition (**CITATION**), which, when coupled with human influences, can directly affect multiple species simultaneously (**a non- fishery example here?**). Ultimately, through direct 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 and food resources (Carpenter et al. 2017; Sass et al. 2017). Human effects on slow moving, abiotic variables like climate will also alter community dynamics. This has been well described in aquatic communities (e.g., **eutrophication, lake browning, bass-walleye degree days, SOS**). Because of the varied ways in which humans influence these systems, and the numerous ways in which organisms in these systems interact with each other and respond to perturbations, aquatic systems often behave in complex, non-linear ways.

These complex interspecific interactions in aquatic systems can result in positive feedback loops that allow a stable state to reinforce itself such that efforts by managers to change the stable state may have no or unintended effects. Walters and Kitchell (2001) described 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 preying on the predators of its juveniles, namely the forage species. Alternatively, the 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 of the top predator. When top predator abundance declines enough, recruitment of new juveniles to the population may decline through the process of depensation where there are so few spawning adults left that recruitment declines in spite of decreased intra-specific competition. The positive feedback loops that enable cultivation-depensation effects demonstrate one mechanism by 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 (even through fishery closure) may have no effect or possibly a negative effect if the associated increase in juvenile production further increases foraging 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, costly, and sometimes irreversible. 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 inter-specific 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) described 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. Considering this, Carpenter et al. (2017) laid 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 the complex inter-specific interactions, regime shifts can occur that are likely to have major implications for 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 inter-specific and trophic interactions among species, and the hysteretic ecosystem-state 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 research addressing stable states and ecosystem-based management have focused on the management of a single species. In fisheries, it is common to focus applied research on a single focal species, even when this species is embedded in a larger community where harvest of multiple species takes place (**Hansen et al. 2015**). 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) used 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 combined to determine the appropriate level of mortality for each species given specific 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, valuation, utility, avidity, 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, or habitat alteration), understanding and leveraging ecological interactions allows managers to make the most of the limited tools at their disposal to keep systems within a safe operating space and to meet the diverse goals of users in this system (Carpenter et al. 2017).

Here, we use an example of a recreational 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 that the adoption of 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 within a hypothetical recreational fishery. Our hypothesis that inter-specific interactions play an important role in determining the appropriate management action leads us to predict that consideration of non-linear dynamics arising from inter-specific interaction leads to more positive and predictable outcomes for managers. Outcomes that are of specific interest here include economic benefits, high angler satisfaction, and a stable state in which the desired species dominates.