Reworking intro for q2 a little

Topic sentences for q2 draft

Interactions between species are often overlooked in natural resource management for simplification.

Several examples of the causes and effects of ineffective management action on fisheries were reviewed in Pine et al. (2009).

These complex intra- and inter-specific 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.

The non-linearity that can arise when dealing with inter-specific interactions, as demonstrated by cultivation-depensation theory, can lead to counterintuitive outcomes and pose a problem for managers who are often limited in the options available to them (Carpenter et al. 2017).

To date, much of the research addressing stable states and ecosystem-based management has focused on the management of a single species.

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.

New topic sentences

Interactions between species are often overlooked in natural resource management in order to simplify complex management problems.

A failure to consider ecological interactions has led managers to implement strategies that have produced unexpected, and in some cases detrimental, results (Pine et al. 2009). – flip this and talk about how if we do understand this, we can use it to our advantage.

These complex intra- and inter-specific 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.

Where consideration of ecological interactions has occurred, researchers and managers alike have typically considered only one managed species interacting with other non-managed species. – reword this so it doesn’t feel like a circle back to ecosystem management.

Here we use an example of a recreational fishery with two managed species to explore how managers can leverage ecological interactions between species achieve their goals.

Interactions between species are often overlooked in natural resource management in order to simplify complex management problems. However, as human influences on ecosystem continue to grow, so does the need to move from single species management to ecosystem-cased management. Ecosystem-based management takes a holistic approach to managing natural resources that includes the interactions of humans within social-ecological systems. Ecosystem-based management can be difficult to implement due to the complex nature of social-ecological systems, where ecosystem services and states of interest are integrated within larger systems ranging across governance boundaries from local to international. Although ecosystem-based management implementation may be difficult, it is nevertheless warranted. Aquatic social-ecological systems, including fisheries, provide excellent examples to explore the difficulties of implementing ecosystem-based management. 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 (Walters et al. 2000; Hansen et al. 2015; Sass and Shaw 2020).

A failure to consider interactions between species has led managers to implement strategies that have produced unexpected, and in some cases, detrimental, results (Pine et al. 2009). Pine et al. (2009) used several case studies to explore why predictions for ecosystem responses to management actions were not met in simple and complex systems. A central theme of these incorrect predictions was a failure to consider interactions between multiple species and life stages (Walters et al. 2000). In aquatic communities, species may be simultaneously in competition with each other and interacting with human use of the system. For example, human-induced climate change can result in altered ice cover regimes, thereby altering species interactions between Arctic char (Salvelinus alpinus) and brown trout (Salmo trutta), likely resulting in decreased Arctic char biomass and systems dominated by brown trout (Helland et al., 2011). Overfishing has interacted with climate change and interspecific interactions to cause dramatic shifts in dominant species on coastal ecosystems around the world (Jackson et al. 2001).

These complex intra- and inter-specific 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 may be compromised through density-independent elevated mortality rates (in contrast to the commonly assumed density-dependent compensatory recruitment and elevated survivorship) (Liermann and Hilborn 1997; 2001; Carpenter 2003; Hilborn et al. 2014; Sass et al. ?). 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. Regime shifts driven by overfishing are one example of the persistence of these new stable states where fish populations are unable to recover even when the fishery is closed for decades (Hutchings 2000).