Project proposal 3: Predation on a habitat-forming prey species: assessing the net effects of prey consumption versus habitat modification

Keywords predation, habitat modification, foundation species, ecosystem services

Introduction and Background Predation has the potential to strongly influence the community structure[1,2] and ecosystem functioning[3] of natural systems. However, the realized effects of predation vary strongly within and among systems,[4] which continues to limit our predictive capability. For example, the diversity of predator species in a system often creates emergent patterns in prey survivorship due to inhibition or facilitation among different predators.[5] Additionally, the physical structure of natural habitats can influence predation strength both positively and negatively,[6] affecting prey mortality and creating feedbacks on the predators themselves.

The variable effects of predation create difficulties in predicting prey population dynamics. Predators reduce prey populations through direct consumption, but they can also impact the community via habitat modification by foraging or other activities[7]. The relative impact of habitat modification by predators may be contingent on temporal scale, as Hastings (2007) showed with the idea of legacy effects of ecosystem engineers when their engineering products outlive the engineer.[8] Additionally, Crain and Bertness (2006) show that habitat modification by ecosystem engineers can vary over environmental stress gradients.[9] While most predators cannot be classified as ecosystem engineers, these concepts are still applicable to non-engineering habitat modification by predators and are critical to predicting the full impact of predator populations on their surrounding community.

The complex interactions between predators, prey, and their physical habitat may be especially apparent in systems, such as oyster reefs and coral reefs, where the prey itself is a habitat-forming species. In such systems, the short-term effects of predation (prey mortality) may be offset by longer-term effects of habitat modification that influence prey recruitment. For example, Boal (1980) demonstrated that harbor seals crush and abrade habitat-forming invertebrates as they haul themselves onshore to rest, thus opening up new space for potential colonization.[10] If these opposing predation impacts vary with context and scale, and if the habitat modification influences recruitment of the foundation species, then there may be a complex intersection between short- and long-term effects of predation on the prey population. Given the role of foundation species in establishing and supporting important ecosystems,[11] the role of predation over time represents a productive area for ecological research.

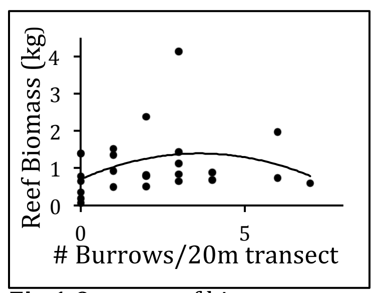

Fig.1 Oyster reef biomass as a function of crab burrow density (20m transects) in Apalachicola Bay, FL.

An example of this predator-prey relationship exists on the subtidal oyster reefs in the southeastern United States. In this region, oyster reefs are a dominant and highly structured habitat, which support a key predator of oysters (the stone crab, *Menippe mercenaria*) that modifies the habitat by creating burrows. While previous research suggests that their abundance deteriorates reefs,[12] our monitoring of this system shows high variation in the relationship between burrow density and reef biomass (Fig. 1) that may be indicative of more complex dynamics of crab predation on oysters over time. For instance, although the effects of crab predation are immediate, the net effects over time may depend on how the burrows and dead shell surrounding the burrows affect oyster recruitment over multiple generations (2 recruitment classes/year in Florida). The reefs in this region also show a noticeable gradient in structural complexity due to a spatially concentrated fishery and massive overharvesting of oysters[13], thus providing an ideal example of how these predation effects may vary over a gradient of structural complexity.

Questions and Goals I will model both the immediate effects of predation on a foundation species prey as well as the potential facilitation via habitat modification on prey recruitment. By comparing the relative magnitudes of these predation effects, I hope to determine the net impact of the predator presence on the prey species over time. Based on my findings, I will ask the question of whether the net effects of this predator change over a gradient of structural complexity as a way to predict prey population dynamics across different spatial contexts.

Methodological Approach

Methods 1 In order to determine the negative effect of predation on habitat-forming prey, I will use coupled differential equations to model predator-prey dynamics in continuous time. I will then examine how the prey population dynamics change by adding the facilitative effect on prey recruitment. Model assumptions will include a Type II specialist predator, density-dependent prey growth, and a constant environment. I will first find the equilibrium solutions of the model and determine their local stability using standard methods, and then determine the effect of each predation parameter on the equilibrium and use simulations to visualize the prey dynamics.

Methods 2 To predict the sensitivity of prey populations based on their habitat condition, I will incorporate a structural component to the model that represents initial habitat condition.
I will analyze the relative importance of this structural effect on the model equilibrium and use simulations to determine whether different habitat conditions change the previously observed patterns of predator-driven prey dynamics.

Expected Results and Implications I expect to see an immediate negative effect of predation on the prey population, however predator consumption may be an insignificant driver of prey dynamics compared to abiotic factors (i.e. salinity changes, overfishing, etc.). I also expect to see a facilitation effect of habitat modification on prey recruitment, but the net outcome between this positive effect and the negative effect of prey consumption will be context-dependent. Degraded habitats with little structure will most likely show recruitment limitation, thus any facilitation effect of predator habitat modification will be strongest in these areas. I don't expect to see a strong facilitation effect in healthy habitats with high structural complexity because ideal recruitment substrate is not a limiting resource. In areas of healthy prey and high levels of physical structure, abiotic factors from anthropogenic activities may be more important drivers of prey dynamics than predator-prey interactions.

By examining the temporally variable effects of a predator population on a foundation-species prey, we gain insight into a fundamental interaction that may have ecosystem-wide impacts. Ecologists and resource managers may be able to incorporate the results of this study into management and restoration plans for threatened habitat-forming species. Additionally, the ability to predict future predator-driven prey dynamics based on the current conditions of a habitat may be a valuable tool for targeting sensitive areas for conservation. Previous studies on predation of foundation species have focused mainly on predator consumption and little is known of feedbacks resulting from the additional impacts of predator habitat modification. Evaluating the variable ways a predator can affect its prey community provides a more complete picture of how these populations interact and how they may drive larger ecosystem processes.

1. Hairston et al. 1960 *The Am Nat* 2. Paine 1966 *The Am Nat* 3. Schmitz 2008 *Science* 4. Shurin 2002 *Ecol Letters* 5. Sih 1988 *The Am Nat* 6. Grabowski et al. 2005 *Ecology* 7. Pringle 2008 *Ecology* 8. Hastings et al. 2007 *Ecology* 9. Crain and Bertness 2006 *Bioscience* 10. Boal 1980 *MEPS* 11. Kefi et al. 2012 *Ecol Letters* 12. Menzel 1958 *Bull of Mar Sci* 13. Wang et al. 2008 *Ecol Modelling*