Modeling Lionfish Management Strategies on the West Florida Shelf

Modelado de Estrategias de Gestión de Pez León en la West Florida Shelf

Modélisation des Stratégies de Gestion des Poissons-lion sur le West Florida Shelf

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EXTENDED ABSTRACT

Invasive lionfish (*Pterois volitans/miles*) threaten to alter marine food webs and reduce fish stocks throughout the western Atlantic, Caribbean, and Gulf of Mexico. Spearfishing and targeted removals have been the primary method for controlling populations and mitigating impacts. Due to a variety of constraints, these efforts have only been effective at local scales (*i.e.,* specific reefs). Policy options for controlling lionfish at larger, potentially basin-wide scales have yet to be explored. Trophic dynamic models, such as Ecopath with Ecosim (EwE), can be used to assess ecosystem-scale impacts stemming from invasive species, and to explore management strategies for controlling populations. We updated an existing EwE model of the West Florida Shelf (WFS) marine ecosystem to include lionfish. Our objectives were to:

i) Estimate lionfish impacts to native WFS reef fish,
ii) Assess the efficacy of direct lionfish harvest to mitigate those impacts,
iii) Evaluate how management strategies for commercially and recreationally important reef fish (*e.g.,* groupers and snappers) could be used to control lionfish and reduce impacts to other species/functional groups, and
iv) Assess ecosystem susceptibility to invasive lionfish as a result of historically high fishing pressure on the WFS.

Lionfish were added to the existing EwE model as juveniles (0 - 6 months) and adults (6+ months) to account for ontogenetic diet shifts and vulnerability to spearfishing. Habitat-specific lionfish densities extracted from the literature were used to estimate lionfish biomass across the WFS. Lionfish diet composition was assimilated from eight studies, and data were weighted based on location, sample size, and data type. Consumption, growth, and maturity parameters were obtained from the literature and adjusted to actual WFS environmental conditions. Invasion scenarios were simulated for 30 years, and evaluated under alternative assumptions about lionfish predation rate limits and cannibalism on juveniles. The relative change in lionfish and native reef fish biomass was modeled in response to changes in both lionfish and reef fish harvest rates (see Figure 1 for simulation scenarios). Parameterization of the original WFS model is described in Chagaris et al. (2015).

Lionfish Biomass

Under lower (25% of current levels), current, and higher (200% of current levels) reef fish harvest rates, lionfish biomass after 30 years is predicted to be 180x, 210x, and 230x greater than 2011 estimates (base Ecopath year), respectively. Fortunately, lionfish harvest is expected to help control populations under each scenario. Our model also suggests that decreasing reef fish harvest rates alone may help reduce lionfish biomass. This is likely due to complex trophic interactions (*e.g.*, dietary overlap) between native fish species and lionfish.

Lionfish Prey Species Biomass

Under all reef fish harvest scenarios, common lionfish prey biomass (*e.g.,* shrimp and reef carnivores and omnivores) is predicted to decline after 30 years, but lionfish harvest is expected to partially mitigate this impact (Figure 1). Similar to terminal lionfish biomass estimates, lowering reef fish harvest is expected to reduce impacts to most of these species. In contrast, vermillion snapper (*Rhomboplites aurorubens*) biomass is expected to increase and lionfish harvest may actually reduce vermillion biomass. This may be a result of lionfish exerting greater predation mortality on vermillion predators than on vermillion directly. As lionfish biomass declines, vermillion predator biomass increases and consumption on vermilion exceeds the predation mortality exerted by lionfish.

Fishery Species Biomass

Under current reef fish harvest levels, commercially and recreationally important species biomass (*e.g.,* amberjack (*Seriola dumerili)*, red snapper (*Seriola dumerili)*, red grouper (*Epinephelus morio)*, and gag grouper (*Mycteroperca microlepis)*) is predicted to decline after 30 years, but lionfish harvest may partially mitigate this impact. This is true for all reef fish harvest levels.

Overfishing and Susceptibility to Invasions

To address the question of ecosystem susceptibility to lionfish, we manipulated the model to allow all fishery species to rebuild for 10 years prior to the invasion. Our model predicted that the invasion would still have occurred even with rebuilt stocks. However, terminal lionfish biomass could have been considerably lower than (approximately 16%) the biomass predicted under current reef fish harvest levels. This suggests that managing a fisheries complex with overall lower fishing pressure may help lessen the magnitude of future invasions.

Possible Scenarios of the Invasion

Projections of lionfish biomass over a 30-year simulation were examined for three likely scenarios: worst case, expected, and best case (Figure 2). All scenarios displayed exponential increases in lionfish biomass from the start of the invasion on the WFS in 2011, and reached stable lionfish biomass levels around 2020. This would imply that lionfish biomass in the region is expected to increase dramatically under all scenarios, but management actions such as lionfish harvest combined with modest reductions in fishing mortality on reef fish can provide control of the invasion.

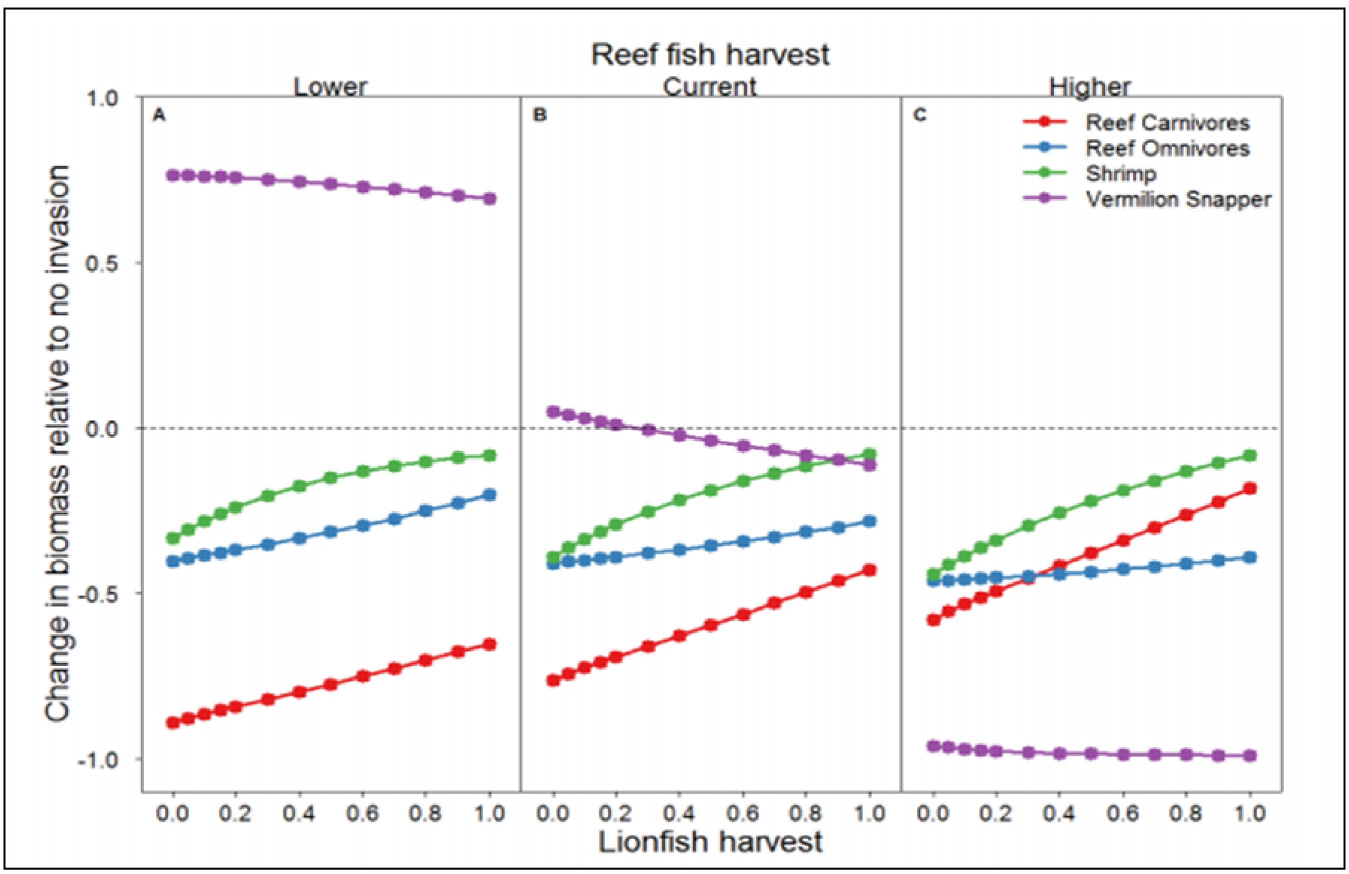

Figure 1. The proportional change in the biomass of common lionfish prey species after 30 years relative to simulated WFS biomass estimates assuming the invasion did not occur. Data plotted above the center line indicate an increase in biomass and data plotted below this line indicate a decline in biomass. Prey species responses were evaluated under three levels of reef fish harvest, including current efforts (B), lower (25% of current effort, A) and higher (200% of current effort, C), and across varying degrees of lionfish harvest (10% incremental multipliers of natural lionfish mortality (M = 0.66/year)).

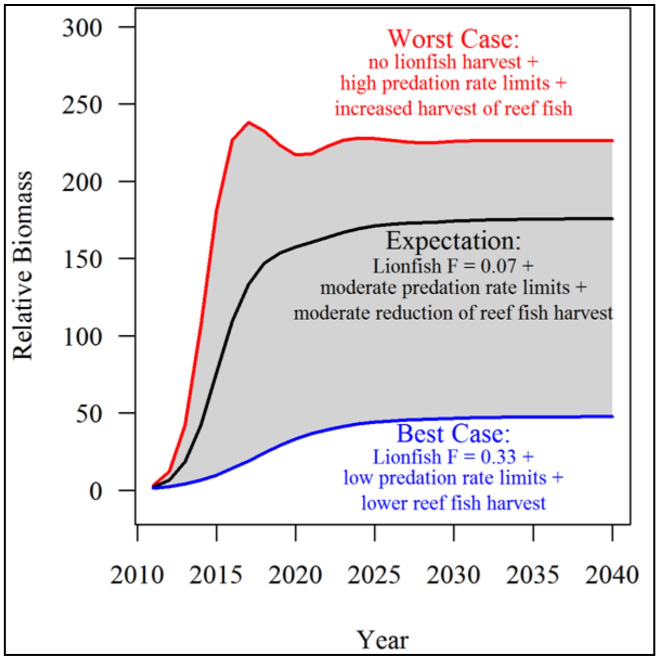

Figure 2. Simulated 30-year change in adult lionfish biomass relative to the 2011 base biomass estimates. *Expected Scenario:* current reef fish harvest, adult lionfish cannibalism on juveniles, reasonable lionfish harvest, and moderate predator effectiveness *(i.e.*, prey vulnerability). *Worst Case Scenario*: higher reef fish harvest, no cannibalism, no lionfish harvest, and high predator effectiveness. *Best Case Scenario*: lower reef fish harvest, cannibalism, high lionfish harvest, and low predator effectiveness.

Conclusions

Results from our model revealed complex trophic interactions that have implications for managing reef fish stocks and mitigation lionfish impacts. Increased lionfish harvest improved the abundance of most mid-level consumers in the food web, indicating a commercial fishery could partially mitigate lionfish ecosystem impacts. Decreased reef fish harvest resulted in reduced lionfish biomass and improved the abundance of most lionfish prey and commercially and recreationally important species. This suggests more conservative fisheries management can indirectly mitigate the invasion and improve native fish stocks.

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