Multiple predator effects & native prey behavioral responses to two non-native cichlids

Ashley E. Porter*[1], Jennifer S. Rehage[1], William F. Loftus[2], and Shawn E. Liston[3]

[1]Oceanographic Center, Nova Southeastern University, Dania Beach, FL, USA*ashlport@nova.edu
[2]United States Geological Survey, Florida Integrated Science Center, Everglades National Park Field Station, Homestead, FL, USA
[3]Corkscrew Swamp Sanctuary, Audubon of Florida, Naples, FL, USA

Introduction

Ecological systems contain multiple predators and prey but few studies have examined the complex interactions, especially with non-native predators. Prey may be evolutionary naïve with such predators and thus exhibit ineffective or inappropriate defense behaviors when faced with a novel threat. Introduced-predator effects may be attenuated or exacerbated depending on interactions with native predators or with previously established non-native predators.

More than 12 non-indigenous fish species are currently established in Everglades National Park (ENP), a large number relative to the small 35-species native fish fauna. A recent biological invasion of ENP (ca. 2002) is that of the African jewelfish, *Hemichromis letourneuxi*. Among the most abundant and well-established non-native fishes is the Mayan cichlid, *Cichlasoma urophthalmus*. We used a field enclosure experiment to assess and compare predation effects of these two non-native cichlids and an aquarium experiment to examine predator tactics and anti-predator behavioral responses.

Research Questions

- Are these two predators functionally redundant (i.e., are predation rates and preferences similar)?
- How do these predators interact (including as a function of size since Mayan cichlids are larger)?
- How do native prey respond to these non-native predators?
- How does anti-predator behavior relate to the vulnerability to predation of prey?

Field Enclosure Experiment

•We conducted an *in situ* replacement series experiment (Schmitz, 2007) in a randomized-block design at the peak of the wet season (October 2007; mean water level 33.4 cm) to compare mortality rates.

Fig. 1. Map of lower ENP, green arrow indicates study site (25° 16.97′ N, 80° 47.88′ W).

Fig. 2. Enclosures were constructed of 1-m^2 polypropylene mesh cubes attached to PVC frames oriented in one row east to west, perpendicular to water flow.

Fig. 3. Ambient floc & periphyton as well as artificial steel stems were added to the enclosures to provide habitat complexity.

Laboratory Behavior Experiment

•Timed trials were conducted in aquaria with similar randomized-block design to record behavioral interactions. Six hourly spot-check observations were taken.

Fig. 4. Variables recorded included prey & predator activity and vertical distribution and predator interactions. Habitat structure comprised 22% volumetrically and water depth matched the field.

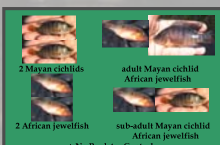

Fig. 5. Treatments used in both experiments.

Flagfish	Eastern Mosquitofish	Bluefin Killifish	Riverine Grass Shrimp	Least Killifish
Jordanella floridae	*Gambusia holbrooki*	*Lucania goodei*	*Palaemonetes paludosus*	*Heterandria formosa*

Fig. 6. Native prey; 6 individuals used for the field study and 2 individuals used for the aquaria study, per species.

Field-Enclosure Experiment

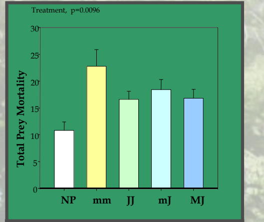

Fig. 7. Total prey mortality for all prey combined.

NP	No Predator Control
mm	2 Mayan cichlids
JJ	2 African jewelfish
mJ	sub-adult Mayan cichlid African jewelfish
MJ	adult Mayan cichlid African jewelfish

•Mayan cichlids have a higher predation rate than African jewelfish.

•There was no evidence that prey experience a release from predation when both cichlids are present.

•Predation rates were unaffected by Mayan size.

•All predator combinations consumed *J. floridae*, particularly with adult Mayan cichlid-African jewelfish.

•*L. goodei* was consumed by Mayan cichlids, but avoided in African jewelfish and adult Mayan cichlid-African jewelfish treatment.

•There was a complete avoidance of *G. holbrooki* across treatments.

•The recovery of *P. paludosus* and *H. formosa* was lowest in the control treatment.

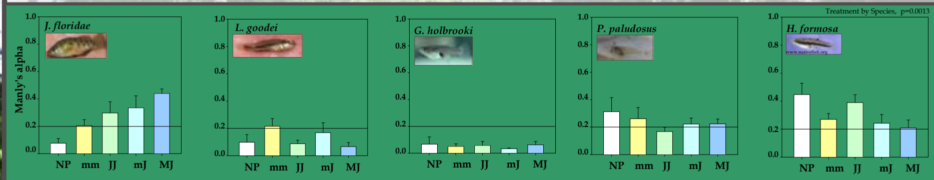

Fig. 8. Prey selectivity indexes by prey species and treatment. The line indicates no preference (a Manly's alpha value of $1/m = 0.2$, where $m = 5$ prey items available).

Laboratory Behavior Experiment

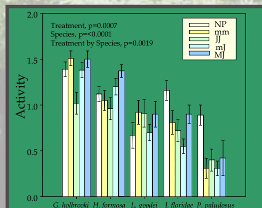

Fig. 9. Prey activity levels by treatment and species scored as 2=active, 1=slightly active, and 0=not active.

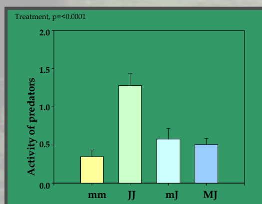

Fig. 10. Predator activity levels shown by treatment, scored in the same way as prey species.

•Prey activity was highest in the absence of predators and lowest with African jewelfish.

•*J. floridae* and *P. paludosus* lowered their activity to all predators whereas *G. holbrooki* lowered activity to the African jewelfish.

•*H. formosa* was more active in the presence of the adult Mayan cichlid-African jewelfish than in either of the single-predator treatments.

•*L. goodei* did not respond to any predator combinations.

•African jewelfish had the highest activity and interaction rates.

•African jewelfish lowered activity when Mayan cichlids of either size were present.

•Both predators overlapped in habitat domain with *J. floridae*, *L. goodei*, and *P. paludosus*, but not *G. holbrooki* or *H. formosa*.

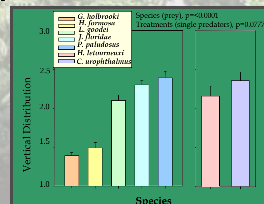

Fig. 11. Vertical distribution of prey and predators by species in the water scored as 1=top, 2=middle, 3=bottom.

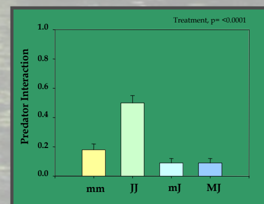

Fig. 12. Predator interactions by treatment, scored as 0=no interaction and 1=interaction.

Conclusions

•Our results showed that the well-established invader had a larger predation effect than the recent invader.

•Both cichlids preyed selectively on *J. floridae* while Mayan cichlids also consumed *L. goodei*.

•The low recovery of *H. formosa* could be due to our difficulty in finding survivors among the large volume of floc and periphyton in the cages. Alternatively, it may have been the result of predation of *H. formosa* by *G. holbrooki*.

•*J. floridae* seemed to be consumed preferentially in the mixed-predator treatment when adult Mayans were present. That may indicate a potential risk enhancement (Sih et al., 1998; Schmitz, 2007) if they experience higher mortality when exposed to multiple predators versus only one predator (Sih et al., 1998).

•Predation rates were similar between adult and sub-adult Mayan cichlids in agreement with Bergmann & Motta (2005) which showed no ontogenetic diet shifts.

•Intraspecific interaction rates were higher for African jewelfish, which may relate to their lower predation rate, and result in a release from predation.

•The habitat domain of the predators appeared to overlap but their predation tactics differed. African jewelfish are active predators whereas Mayan cichlids appear to have a sit-and-wait hunting style (Schmitz, 2007). Little interspecific interactions were observed despite the fact that they overlap in domain, which could be attributed to their difference in activity.

•The habitat domain of the predators overlapped with certain prey which were the most consumed by the predators.

•Prey showed significant behavioral variation in response to the two predators.

•Predators consumed prey that did not respond, and prey that responded indiscriminately to the predation threat. This indiscriminant response may have been ineffective.

Implications

This study provides insight into the nature of interactions between African jewelfish, Mayan cichlids, and the native Everglades aquatic-animal community. It is important to determine if predation by the non-native cichlids poses a formidable threat to the native community, and if range expansion by African jewelfish will result in negative impacts to areas of the Everglades presently uncolonized. Invasive species are a major conservation concern in the restoration of the Everglades and may be affected indirectly by CERP actions. For instance, the projected removal of 386 km of canals and levees will remove canal habitat that is home to a number of non-native fish species, and that seem to be cold-temperature refuges, allowing recolonization of marshes after severe winters. However, new structures and canals are also planned to move water in CERP projects, and ramifications for invasive species should be considered in that planning. Overall, restoration should enhance Everglades habitats and the functional quality of the ecosystem, which has been shown by research to benefit native species to the detriment of non-native taxa.

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Acknowledgments

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