Why Ecophysiology Matters: Tools to Assess Invasiveness of Non-Native Aquatic Fauna in the Everglades

Pamela J. Schofield and William F. Loftus

Rationale for studying ecophysiology

When a newly introduced species is detected, we often know little about its biology or ecology. Ecophysiology studies provide rapid assessments of physiological tolerances to estimate the potential for that organism to disperse across the landscape. Ecophysiology research addresses the question *"What natural barriers will limit a species' dispersal?"* Those data are important even for non-native species that have been established in the Everglades for years. The Everglades is a "Living Laboratory of Change", and as habitats are restored, those species may encounter new conditions that may hinder or facilitate their success. Together with literature surveys and studies of life-history, behaviour and ecology, ecophysiology research lends insight into the potential invasiveness of non-native species.

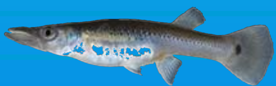
Black acara, *Cichlasoma bimaculatum*

Spotted tilapia, *Tilapia mariae*

Mayan cichlid, *Cichlasoma urophthalmus*

Ecophysiology measures

Traditional physiological studies primarily focus on cellular-level mechanisms (e.g., changes in hormone or haemoglobin levels, number of chloride cells). We use whole-animal, integrated-response measures such as survival, growth, and cessation of feeding. Those measures integrate multiple responses (e.g., metabolism, blood chemistry, immunology) and provide results that are useful to natural-resource managers.



Pike killifish, *Belonesox belizanus*

The role of field experiments

Increasingly we are incorporating field components into our ecophysiology experiments. Field testing allows verification of our laboratory results under more natural conditions.

Laboratory experiments

Field studies provide essential information on distribution, abundance, ecology and movement of species, the foundation of our knowledge regarding non-native species. However, field studies produce mainly correlative relationships of non-native species to environmental variables such as salinity, temperature or dissolved oxygen. By bringing those species into the laboratory, we can measure precisely their tolerances to specific environmental factors by holding all other variables constant.

Laboratory studies are conducted at many scales, from small aquaria to mesocosm tanks.

Burmese python, *Python molurus bivittatus*

Recent ecophysiology publications (reprints available):

Hart, K., P.J. Schofield & D.R. Gregoire. 2010. Salinity tolerance of hatchling Burmese pythons (*Python molurus bivittatus*) from the Everglades, Florida (USA). In Prep. For Submission to: *Journal of Experimental Marine Biology and Ecology.*

Schofield, P.J. & D.H. Huge. 2010. Low-temperature tolerance of two non-native fishes (*Hoplosternum littorale* [Hancock 1828], *Cichlasoma bimaculatum* [Linnaeus 1758]) established in south Florida USA. Submitted: *Florida Scientist*

Langston, J.N., P.J. Schofield, J. E. Hill & W. F. Loftus. 2009. Salinity tolerance of the African jewelfish *Hemichromis letourneuxi*, a non-native cichlid in south Florida, USA. In Press: *Copeia*

Schofield, P.J., W.F. Loftus, R.M. Kobza, M.I. Cook & D.H. Slone. 2009. Tolerance of nonindigenous cichlid fishes (*Cichlasoma urophthalmus, Hemichromis letourneuxi*) to low temperature: laboratory and field experiments in south Florida. *Biological Invasions.* Published online 22 Nov 2009;

Schofield, P.J. & L.G. Nico. 2009. Salinity tolerance of non-native Asian swamp eels (Teleostei: Synbranchidae) in Florida, USA: comparison of three populations and implications for dispersal. *Environmental Biology of Fishes* 85: 51-59.

Schofield, P.J., W.F. Loftus & J.A. Fontaine. 2009. Salinity effects on hypoxia tolerance by the non-native Mayan cichlid (*Cichlasoma urophthalmus*) from Florida Everglades wetlands. *Journal of Fish Biology* 74: 1245-1258.

Schofield, P.J., W.F. Loftus & M.E. Brown. 2007. Hypoxia tolerance of two centrarchid sunfishes and an introduced cichlid in karstic Everglades wetlands of southern Florida, U.S.A. *Journal of Fish Biology* 71 Sup D: 87-99.

Schofield, P.J. , M.E. Brown & P.F. Fuller. 2006. Salinity tolerance of goldfish, *Carassius auratus*, a non-native fish in the United States. *Florida Scientist* 69: 258-268.

Schofield, P.J. 2003. Salinity tolerance of two gobies (*Microgobius gulosus, Gobiosoma robustum*) in Florida Bay (USA). *Gulf of Mexico Science* 21: 86-91.

Examples of recent ecophysiology experiments

Brown hoplo, *Hoplosternum littorale*

Low-temperature tolerance

Understanding how well tropical, non-native fishes tolerate cold temperatures is critical to predicting their potential range and developing management options for control. We determined the low-temperature tolerances of four non-native fish species from the Everglades and examined salinity effects on cold tolerance for two of them. We corroborated our laboratory results by performing a field experiment wherein fishes were caged in natural (marsh, solution hole) and man-made (canal, ditch) habitats during a cold snap.

Results:

- Brown hoplo was significantly more tolerant to low temperatures than the cichlids we tested (Mayan cichlid, African jewelfish, black acara).
- Salinity had only minimal effects on low-temperature tolerance of African jewelfish and Mayan cichlid; however, it reduced their ability to recover after they lost equilibrium.
- The field study found that ditches as shallow as 50 cm were sufficiently buffered thermally to protect sensitive tropical fishes from a cold snap.

Management implications:

Ditches and canals would have to be filled in (or water levels lowered) to < 50 cm to expose non-native fishes to fatal cold temperatures. Laboratory-based studies such as these could be used in the future to assess risk of invasion and range expansion by new invaders.

Hypoxia tolerance

An important attribute of wetland-adapted fishes is their ability to tolerate periods of low dissolved oxygen (hypoxia). We tested the hypoxia tolerance of a new invader (African jewelfish) and two native sunfishes (dollar sunfish and warmouth). We also tested the hypoxia tolerance of the non-native Mayan cichlid at three salinities (freshwater, brackish and marine).

Results:

- African jewelfish was better-adapted to hypoxia than Mayan cichlid or native sunfishes.
- Salinity had no effect on Mayan cichlid hypoxia tolerance.

Management implications:

Hypoxia will not restrict African jewelfish or Mayan cichlids from continuing to expand across south Florida. Water-management practices that alleviate extreme hypoxic conditions (e.g., < 1 mg L^{-1}) will enable native fishes to occupy seasonally hypoxic habitats (e.g., solution holes). Habitats with dissolved-oxygen levels less than 1 mg L^{-1} will favour survival of non-native fishes over native species.

Salinity tolerance

Some non-native fishes established in the Everglades are known to tolerate salinity (e.g., Mayan cichlid); however, this information is lacking for more recent invaders. Salt-tolerant species often invade estuarine habitats and use them as "salt bridges" to disperse into new watersheds. We have tested the ability of two non-native fishes (African jewelfish, Asian swamp eel) and the Burmese python to tolerate saline waters. (*Sea water is 35 ppt*).

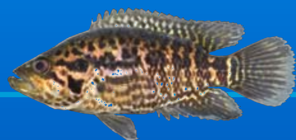
Results:

- The Asian swamp eel withstood acute transfer from freshwater to about 16 ppt , and could survive salinities up to 14 ppt for about 60 days.
- The African jewelfish survived salinities up to 60 ppt when acclimated gradually and withstood acute transfer from freshwater to 20 ppt with 100% survival.
- Burmese python hatchlings were capable of surviving about one month with access to full-strength sea water only (no freshwater). Please visit our poster on this experiment.

Management implications:

Understanding which species can inhabit estuarine or marine waters informs natural-resource managers of the need to monitor for them. Additionally, this information allows scientists to predict potential geographic extent of the invasion. This is especially important in the Everglades, where sensitive estuarine wetlands might be vulnerable to disturbance by non-native species.

Blue tilapia, *Oreochromis aureus*



Jaguar guapote, *Cichlasoma managuense*

African jewelfish, *Hemichromis letourneuxi*

Contact Information

Pamela J. Schofield
USGS, Southeast Ecological Science Center
7920 NW 71st Street, Gainesville, FL 32653
352.264.3530; pschofield@usgs.gov

William F. Loftus
Aquatic Research & Communication, LLC
1759 NW 20th St.
Homestead, FL 33030
305.951.8772; arc_wfl@bellsouth.net

All fish photos by Howard Jelks (USGS) except hoplo (Noel Burkhead, USGS).