“Can’t get there from here”: Hydrological connectivity impacts temporal and spatial patterns of fish community structure

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Abstract

Habitat complexity and connectivity affect the movement of fish across a landscape and can shape aquatic communities in a hydrologically variable environment. The role of connectivity in shaping wetland and estuarine fish communities has not been emphasized in past studies. We documented spatial and temporal patterns in fish community structure and standing crops along salinity and nutrient gradients in two sloughs of the Everglades National Park. Forty-nine species of fish were collected from January 2000 to April 2004 at six sampling sites associated with the Florida Coastal Everglades Long-term Ecological Research (FCE-LTER) program. These sites span the oligohaline zone in the Shark River (SRS) and Taylor (TS) Sloughs, Everglades National Park. We noted regional differences in species composition and total fish biomass through analysis of Bray-Curtis dissimilarity matrices. Aerial photography and LIDAR data indicated differences in habitat connectivity between transitional mangrove habitats and downstream fringing mangroves in these two systems. We propose a conceptual model that relates fish biomass and an index of habitat connectivity to regional sites along the environmental gradients. The Florida Everglades is currently the focus of a major restoration effort that will alter freshwater flow to the oligohaline areas. Fish biomass is a vital link of energy transfer in the food web, and baseline data that links freshwater areas to mangrove regions are needed. Secondary production responses to changing habitat structure associated with water management practices must be understood if future management success is to be realized.

Keywords: Community structure, Habitat connectance, PRIMER, Oligohaline gradients, Florida Everglades

Introduction

Communities are structured by interactions of resource availability, biotic interactions, disturbance, and landscape features. However, landscape and habitat connectivity are often overlooked as important factors in aquatic systems, and particularly for mobile taxa such as fish.

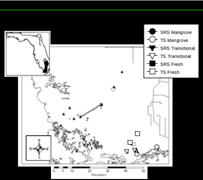

Figure 2. Map of Everglades National Park and fish sampling locations in SRS and TS. Gray boxes indicate location of aerial photography and black lines indicate LIDAR transects.

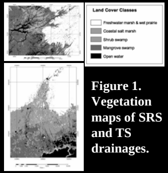

Figure 1. Vegetation maps of SRS and TS drainages.

Landscape features shaping water flow and connectance of suitable habitat may form physical barriers to full use of aquatic habitats. Access for movement of animals across ecotones is thought to be important in sustaining populations of many estuarine-dependent animals. Habitat features can facilitate or impede movement across a landscape. Vegetation maps of SRS and TS drainages indicate more spatial heterogeneity in the SRS drainage than in the TR drainage, when compared at the same spatial scale (Figure 1). We report results from a five-year observational study of fish communities in the upstream freshwater wetlands, transitional wetlands, and downstream estuarine zones of the Shark and Taylor Slough drainages (Figure 2).

Results

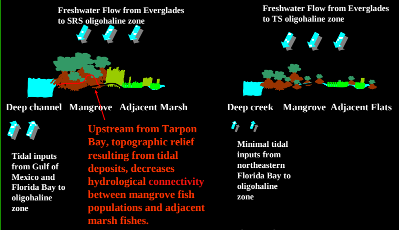

Figure _. Cartoon illustrating typical profiles of the SRS and TS mangrove regions. Note the natural berm present in SRS that is absent in the TS dwarf mangrove region.

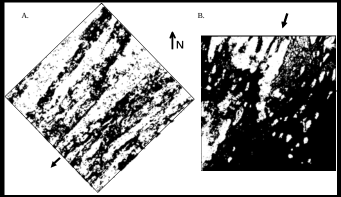

Figure _. Patterning of freshwater sloughs from color infrared aerial photography. Each panel is 1km square and oriented along the direction of flow (arrows). Black areas are standing water while white areas are primarily dense sawgrass strands and tree islands in both SRS (A.) and TS (B.).

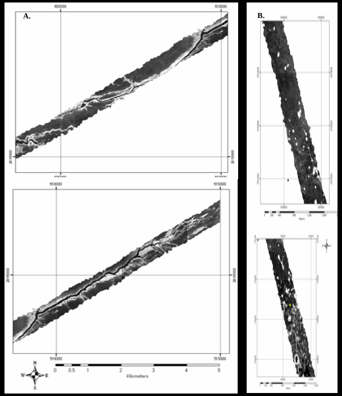

Figure _. Estimates of bare ground elevation from LIDAR imagery. A. SRS. Estimated ground elevations are scaled so that water level is pure black and any elevations >1.5m are pure white. B. TS.

Landscape Patterns

- In upper SRS, 1-m resolution color infrared aerial photography in the early dry season (February 1999) shows sloughs holding water cut off from the main channel and each other by sawgrass ridges running parallel to the main channel (Figure _a). Therefore, fish cannot easily move across the landscape perpendicular to water flow.
- In contrast, the equivalent section of TS has high connectedness among wet areas laterally as well as longitudinally (Figure_b), allowing both water and fish to drain out perpendicular to the channel and into the lowest, longest hydroperiod refuges.
- Bare ground elevations estimated from last-returns of 1-m resolution LIDAR suggest the presence of dense mangroves and/or topographic relief along channels of Avocado Creek and Rookery Branch, north of Tarpon Bay (Figure _a).
- These maps suggest that surface flow and fish movements are less connected between the mangrove transition and the main channels of this region than in other portions of our study (Figures _ and _).
- The presence of narrow ecotones is in marked contrast to the mangrove area associated with Taylor River (Figure _b). This area displays much less pattern in the topographic relief and lacks a clear channel at the scale resolvable from our LIDAR data.

Standing Crops and Fish Community Composition

- We collected 49 species from the 6 study regions between 2000 and 2005
- Between 2000 and 2004, only 14 species were collected in the SRS Mangrove region compared to 29 species in the TS Mangrove region.
- Contrary to our predictions, fish biomass was consistently greatest at the SRS Fresh and TS Mangrove regions (average biomass from 2000 through 2004: 2.40 g/m^2 and 2.50 g/m^2, respectively) and least at the SRS Mangrove region (average biomass from 2000 through 2004: 0.58 g/m^2; Figure _).
- Community structure varied among the four study regions analyzed (Figure _; R=0.411, p=0.001)
- Of the 25 species collected at the upstream freshwater study sites, 17 were restricted to freshwater (69%); 5 of those were limited to TS and 3 to SRS. Five of the 13 species collected at SRS Mangrove sites were only found there (38%), while 11 of the 27 fishes collected at the TS Mangrove sites were only found there (40%).
- Though all regions are distinguishable by ANOSIM, the SRS Mangrove region displays greater separation than the other regions in our nMDS plot (Figure _). This separation resulted from the presence of several species typical of saline conditions, some of which were not collected in the TS Mangrove region.
- A number of species typical of freshwaters were also collected at the TS Mangrove region, and data from this regions clustered between the freshwater sited and the SRS Mangrove region (Figure _).
- The “transitional” sampling regions in both drainages were primarily home to fish that lived throughout the salinity gradient.

Implications for Management

- There are a number of caveats to this study, but our use of LIDAR in mangrove habitats is intended to be though-provoking, but needs more evaluation and ground-truthing.
- Everglades restoration is expected to increase the amount of freshwater reaching the mangrove zone by restoring some of the “natural” sheetflow.
- The change in water flow is likely to affect the habitat connectances in long- and short- hydroperiod marshes as well as linkages between mangroves and their surrounding marsh habitats in the transitional zones.
- This issue of habitat connectance should be explored in future work to determine whether new connections between previously disconnected habitats will affect fish standing crops and community composition.

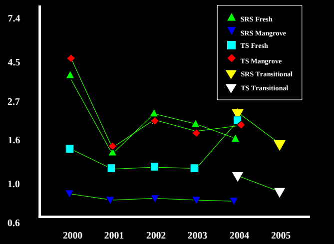

Figure _. Least-squares estimated annual average standing crops in six study regions. Means +/1 one SE are reported.

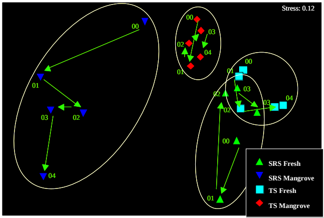

Figure _. nMDS illustrating changes in fish community composition from 2000-04. Plots illustrate regional yearly means species-specific biomass to reduce clutter; statistical tests were conducted on site by sampling event data.

A. Analysis of variance

Effect	df	F	p
Region	5, 57.1	16.28	<0.001
Site(Region)	8, 132	3.46	0.001
Year	4, 32.7	2.65	0.051
Site*Year(Region)	28, 125	0.76	0.803
Site*Season(Region)	14, 131	1.28	0.226
Region*Year	12, 46.9	0.84	0.607
Region*Season	8, 42.5	2.64	0.019

B. Tukey’s pairwise comparisons between regions.

Regions Contrasted		Pr > |t|
SRS Mangrove	SRS Fresh	<.0001
SRS Mangrove	TS Mangrove	<.0001
SRS Mangrove	TS Fresh	<.0001
SRS Fresh	TS Mangrove	0.017
SRS Fresh	TS Fresh	0.002
TS Mangrove	TS Fresh	0.336

Table 1. Results of statistical analysis of fish biomass. A. ANOVA summary table. Some degrees of freedom are not whole numbers because Satterthwaite’s formula was used for calculation. B. Tukey’s pairwise comparisons between regions.

Fish Community Composition

Species	Common Name	SRS Fresh	SRS Mangrove	TS Fresh	TS Mangrove
Ameriurus natalis	yellow bullhead	4.7	0.0	1.4	0.0
Strongylura notata	redfin needlefish	0.0	15.2	0.0	tr
Cyprinodon variegatus	sheepshead minnow	tr	5.7	1.9	10.6
Fundulus chrysotus	golden topminnow	3.6	0.0	9.9	tr
Fundulus confluentus	marsh killifish	4.1	1.9	5.8	5.0
Fundulus grandis	gulf killifish	0.0	7.5	0.0	2.5
Jordanella floridae	flagfish	16.8	0.0	16.3	tr
Lucania goodei	bluefin killifish	7.8	0.0	14.4	tr
Lucania parva	rainwater killifish	0.0	5.3	0.0	5.7
Gambusia holbrooki	eastern mosquitofish	9.0	0.7	6.4	2.1
Heterandria formosa	least killifish	3.2	0.0	1.1	tr
Poecilia latipinna	sailfin molly	10.3	5.7	1.3	15.8
Lepomis spp.	unidentified sunfishes*	tr	0.0	tr	5.7
Elassoma evergladei	Everglades pygmy sunfish	0.6	0.0	2.3	tr
Lepomis punctatus	spotted sunfish	5.7	0.0	3.6	0.8
Gerridae spp.	unidentified mojarras	0.0	0.0	0.0	tr
Cichlasoma uropthalmus	Mayan cichlid	14.7	29.1	25.2	42.5
Bathygobius soporator	frillfin goby	0.0	6.4	0.0	0.0

Table 2. Summary of fish community composition at our 4 study regions (transitional sites not included); only species influential in community ordination are reported. Relative biomass (proportion of total) is reported. *probably spotted sunfish.

Conceptual Model

We developed a simple conceptual model to summarize our hypotheses derived from these data (Figure 8). We propose that fish biomass and species richness increases as a function of connectivity between adjacent habitats in this ecosystem, primarily because of hydrological fluctuations on the daily, seasonal, and yearly time scales. Tidally flooded forest bordering the Shark River dries once or twice daily, leaving very limited aquatic refuge for fishes. The only option for most species is to move into the deep channels of the Shark River because passage to nearby transitional mangrove habitats is blocked.

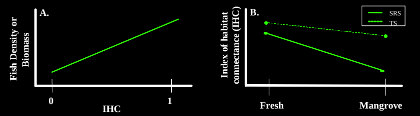

Figure 8. Conceptual model relating fish biomass and an index of habitat connectivity to regional sites along environmental gradients. A. Hypothesized relationship between fish biomass and the index of habitat connectance (IHC), where 0 represents no connectivity between patches and 1 represents complete connectivity. B. Proposed relationship between IHC and study regions.

Acknowledgements

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