Do Range Size and Environmental Variables Predict the Benthic-to-Pelagic Shift of North American Minnows?

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Abstract

This study aims to investigate the ecological and evolutionary mechanisms driving the shift of North American minnows from benthic to pelagic zones in freshwater ecosystems. Our finding of an on average larger range size in benthic species compared to pelagic species suggests that there are possible predictors of this transition. Through an analysis of species distribution data, including range size, and an examination of the environmental conditions within these ranges, this research examines the factors influencing this microhabitat shift and its potential consequences on ecosystem dynamics.

Background

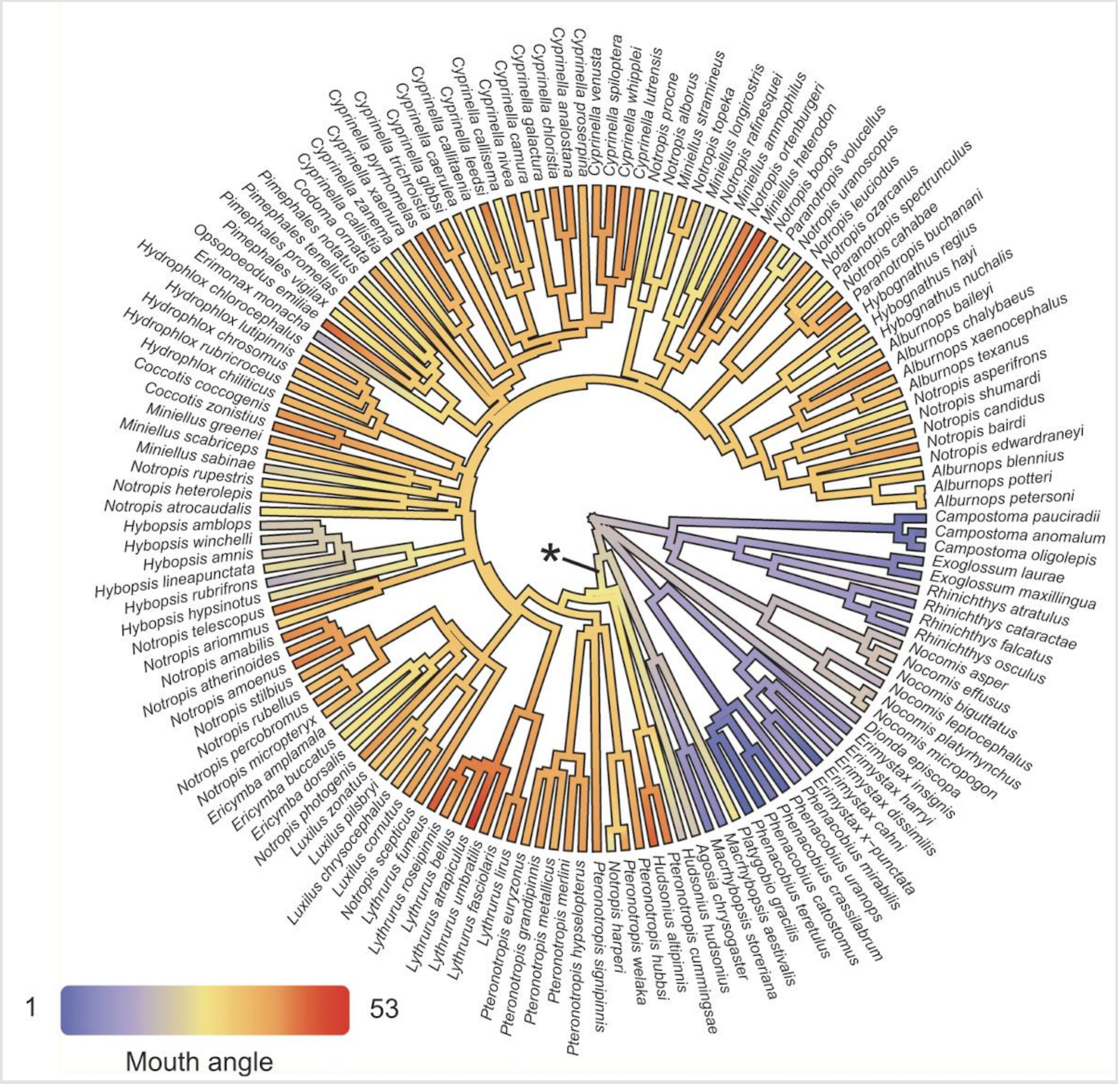

Fig. 1: Evolutionary history of mouth angle among leuciscid fishes (Burress and Hart, 2024)

The mouth angle of minnows is associated with their zone in the water column. Benthic species, depicted in blue, have inferior mouths while pelagic species, depicted in orange, have superior mouths. The phylogenetic tree above illustrates the shift from benthic-to-pelagic species, highlighting their divergence in their morphology and zone over time.

Materials

The study focused on 58 distinct minnow species from various assemblages within the Leuciscidae family, representing a mix of both benthic and pelagic species. To create the species' ranges, FishNet2 was used to gather the locations of various institutions' catalogued specimens. These locations were exported into presence points in QGIS. Then using the Minimum bounding geometry tool in QGIS' Vector Geometry, a Convex Hull was generated for each species' range. This polygon allowed us to visualize and quantify the range size.

Methodology

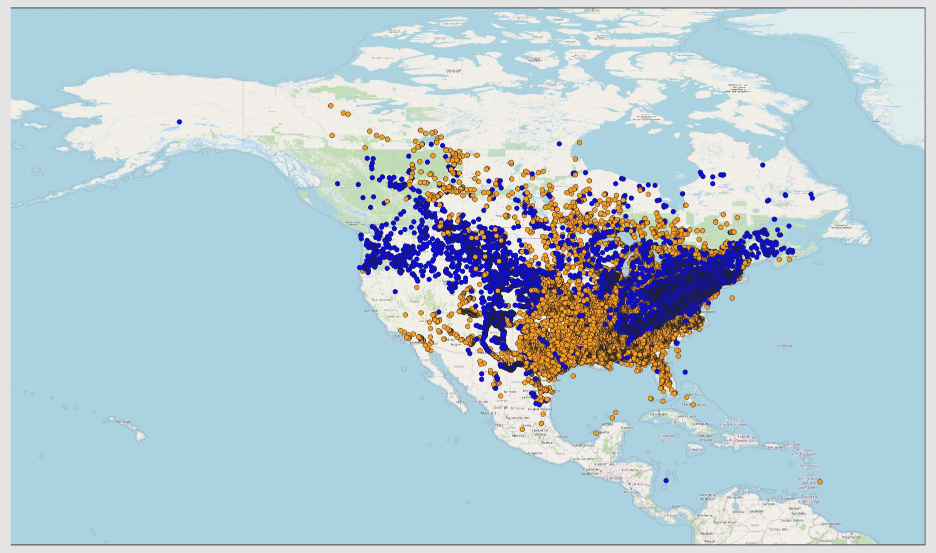

Fig. 1: Complete range sizes of all 58 study species

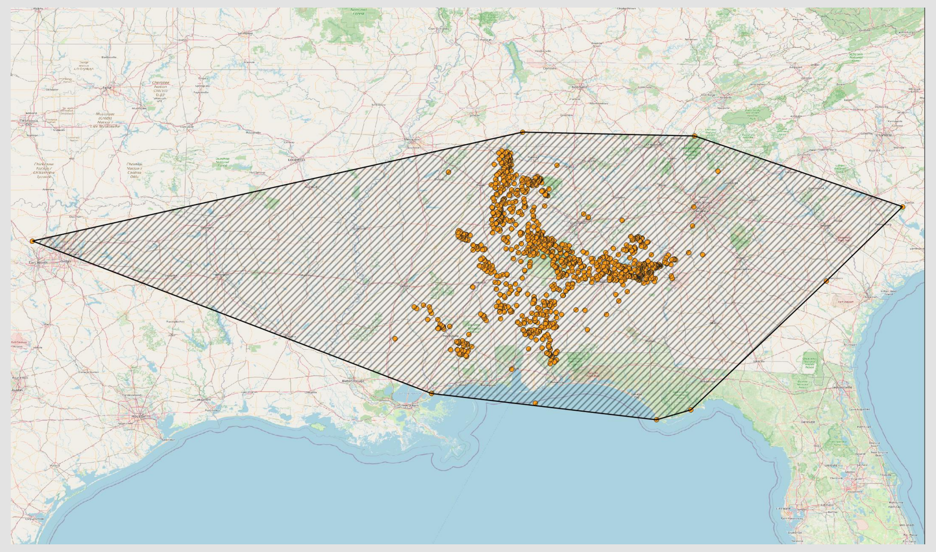

Fig. 2: Uncorrected range size and convex hull of *Notropis baileyi*

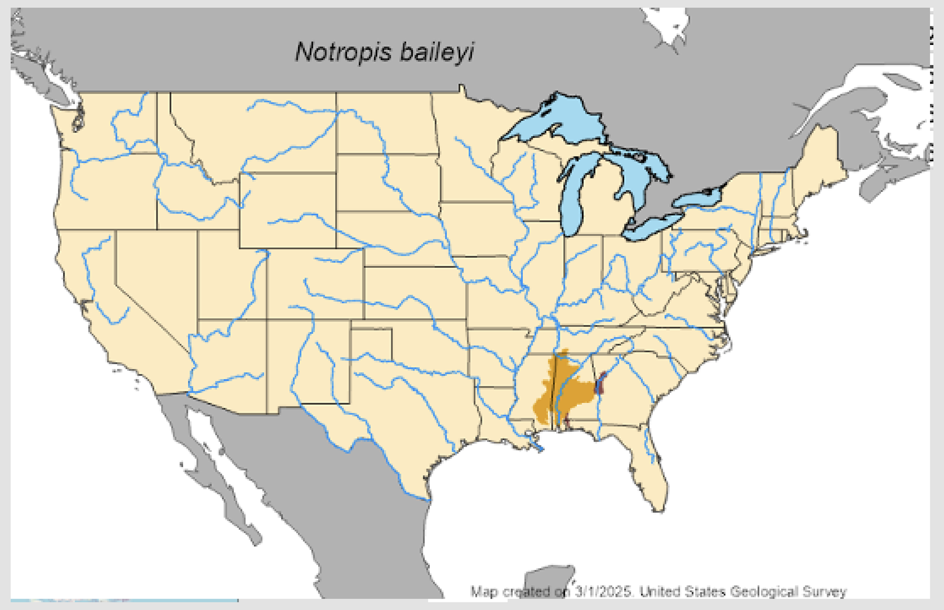

Fig. 3 Range size of *Notropis baileyi* used for correction (USGS)

Results

Benthic Species	Area (°)
Campostoma anomalum	801.6852826
Campostoma oligolepis	168.8001358
Campostoma pauciradii	5.906573457
Erimystax dissimilis	155.5626194
Erimystax insignis	17.25654496
Exoglossum laurae	26.20711781
Macrhybopsis aestivalis	309.6190197
Macrhybopsis storeriana	339.9467779
Nocomis leptocephalus	134.520853
Nocomis micropogon	238.5100728
Nocomis platyrhynchus	4.490352909
Phenacobius catostomus	9.417246385
Phenacobius teretulus	5.315538267
Rhinichthys atratulus	1574.609855
Rhinichthys cataractae	1559.637485

Pelagic Species	Area (°)
Notropis baileyi	56.18952
Notropis texanus	355.9992
Notropis coccogenis	44.7656
Luxilus zonistius	21.50792
Cyprinella callistia	24.79839
Cyprinella galactura	102.4895
Cyprinella gibbsi	5.931208
Cyprinella lutrensis	892.7547
Cyprinella spiloptera	360.2308
Cyprinella trichroistia	17.17947
Cyprinella venusta	207.9915
Ericymba amplamala	25.7245
Notropis amplamala	40.82374
Hudsonius hudsonius	2117.596
Notropis hudsonius	1261.097
Hybognathus hayi	74.17444
Hybopsis amblops	463.998
Hybopsis lineapunctata	10.59943
Hybopsis winchelli	38.70328
Notropis chiliticus	12.5353
Notropis chrosomus	29.53663
Luxilus chrysocephalus	258.6279
Luxilus zonatus	102.2
Lythrurus bellus	54.65441
Lythrurus fasciolaris	94.89009
Lythrurus fumeus	133.2255
Notropis ammophilus	36.14692
Notropis longirostris	35.08716
Notropis scabriceps	13.43305
Notropis atherinoides	1263.225
Notropis cahabae	0.192602
Notropis edwardraneyi	58.10114
Notropis leuciodus	109.0111
Notropis micropteryx	135.6708
Notropis photogenis	87.54302
Notropis stilbius	37.79407
Notropis telescopus	103.497
Notropis uranoscopus	5.336311
Opsopoeodus emiliae	303.0117
Notropis vollucellus	96.608
Pimephales vigilax	522.7116
Pteronotropis euryzonus	6.227729
Pteronotropis welaka	50.86285

	Avg. Area (°)	St. Dev. (°)
Benthic Species	356.765698	533.5594
Pelagic Species	224.946127	419.0233

Acknowledgements

Burress, E. D., & Hart, P. B. (2024). Pelagic zone is an evolutionary catalyst, but an ecological dead end, for North American minnows. *Evolution*, *78*(8), 1396–1404. https://doi.org/10.1093/evolut/qpae062

https://thefisheriesblog.com/wp-content/uploads/2018/09/minnows21.jpg
https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=583

Conclusion

We did observe a pattern in range size and environmental conditions that gave insight into the benthic-to-pelagic shift of North American Minnows. On average, benthic species tend to have larger range sizes, which could suggest they are more adaptable to a wider variety of environmental conditions. As bottom feeders, they do not rely on unpredictable food sources but instead depend more on lithology. Their ideal habitat preferences being reliable suggests that they are more capable of occupying a variety of more diverse, widespread environments.

In contrast, pelagic species, which occupy the open water column, are more susceptible to fluctuating conditions, such as food sources, temperature, and water chemistry. Since these species are impacted by more specific environmental conditions needed for survival, their range size would naturally be more constrained.

A noticeable change in habitat selectivity could serve as an indicator for this microhabitat shift. Benthic species being pressured, whether by anthropogenic factors or natural changes, to reduce their range size or adjust their habitat preferences could be a signal for the need of a benthic-to-pelagic shift. Such pressures could provide a basis for understanding this evolutionary pattern.

Next Steps

- Further analysis of specific environmental conditions and their significance would greatly improve our understanding of the benthic-to-pelagic shift of North American minnows.
- Refining the range size analysis by excluding river basins without fish presence from the convex hull would improve the accuracy of our estimates.
- Reprojection of convex hulls from degrees to meters, again improving the accuracy of our estimates.