University of Kentucky

From the Selected Works of Benjamin L. Blandford

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Expert Systems Model for Kentucky Arrow Darter Habitat in the Upper Kentucky River Basin

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Available at: https://works.bepress.com/ben_blandford/20/

GIS-Based Predictive Habitat Model

Expert-systems modeling for
threatened and endangered species

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- Research Background
- Aquatic species considered:
 - Kentucky arrow darter
- Methods
- Model Results
- Discussion
- Other species considered (time permitting)
 - Blackside dace

- NEPA
- Threatened and Endangered Species Act
- KYTC must conduct species sampling in areas of potential T&E habitat
- Model designed to be a tool for biologists to use when assessing a stream

- Methodology adapted and modified from a previous predictive archaeological model developed by KYTC/KTC.
- Designed to harness the existing knowledge of experts in the subject area to create a spatially explicit model of likelihood
- Not a “biologist in a box”

Kentucky Arrow Darter

- Candidate for federal listing by USFWS
- Has disappeared from significant portions of its historic range
- Habitat degradation linked to human influences, including mining, logging, agriculture, and development.

Image: www.fws.gov

Kentucky Arrow Darter

- Endemic to upper Kentucky R. system
 - Upstream from confluence of Kentucky R. and Red R.
- Appx. 13,600 km of streams

A GIS-Based, Expert-Driven, Weighted Model

1.

Variable
Selection

Expert
Input

- Stream gradient
- Canopy cover
- Land cover
- Riparian area
- Stream order

2.

GIS Data Gathering

Data Source	Description	Variable(s) Derived
Digital Elevation Model	10 m resolution digital elevation model from USGS	Stream Gradient
Geologic Structures 24k	This data set is derived from the 7.5-minute geologic quadrangle maps (scale 1:24,000)	Riparian (Alluvium) Width
National Hydrologic Dataset	Stream network for the Kentucky River Basin (1:24000)	All Variables
Gap Analysis	Land cover data from the Southeast Gap Analysis Project	Land Cover
LANDFIRE	Existing Vegetation Cover as percent cover of the live canopy layer for a 30-m grid cell.	Forest Canopy

3.

Variable
Parameterization

Expert
Input

Habitat Factor	(Low)	← Suitability →	(High)	
	1	2	3	4
Gradient (stream level)	>6 percent	4 – 6 percent	2 – 4 percent	<2 percent
Canopy (percent coverage)	0 – 50 percent	50 – 70 percent	70 – 90 percent	>90 percent
Riparian Vegetation	Cultivated, Developed, Barren	Grass, Herbaceous, Pasture (hay)	Shrubs, Scrub	Forested
Riparian Zone Width	<6 meter	6-12 meter	12-18 meter	>18 meter
Stream Order (Strahler)	6 – 7	1	4 – 5	2 - 3

4.

GIS Data Processing

- Model created using ArcGIS 10.1 and *ET GeoWizards*
- Streams in model divided into appx. 100 m segments derived from the USGS National Hydrologic Dataset 24k
- Resulted in 132,783 segments
- These segments are the basic unit of analysis for each variable created

4.

GIS Data Processing

Stream Gradient

- Calculated as the elevational difference between each 100 m segment divided by the length of the segment.
- Endpoint elevation derived by finding the minimum cell value using an 8-neighbor classification around each endpoint location.

4.

GIS Data Processing

Canopy

- LANDFIRE data describe the portion of the forest floor covered by the vertical projection of tree crowns.
- Data derived from Landsat imagery and spatially explicit biophysical gradients to generate a percent canopy cover at 30 m resolution.

4.

GIS Data Processing

Land Cover

- Land cover data extracted from the Southeast Gap Analysis Project.
- Land cover data for the Kentucky River basin at a resolution of 30 m.

4. GIS Data Processing

Riparian Area

- Two components of riparian area already covered by other habitat factors: canopy and land cover.
- This variable considers the extent of alluvium associated with the stream network.
- Average alluvium width calculated for each 100 m stream segment.

4. GIS Data Processing

Stream Order

- Streams in this basin range from an order of 1 (feeder streams) to 7 (Kentucky River).
- Python script developed to calculate the stream order associated with each stream segment.

- Gradient: 30 percent
- Canopy: 20 percent
- Land cover: 10 percent
- Riparian width: 10 percent
- Stream Order: 30 percent
- Two overarching rules for model

All stream segments receive an overall habitat suitability score of 1-4:

- 1) Very unsuitable
- 2) Unsuitable
- 3) Suitable
- 4) Very Suitable

6. Model Testing Against Presence Data

- Obtained Kentucky arrow darter presence data from USFWS.
- Includes 75 arrow darter occurrences in the upper Kentucky River watershed.
- Precision and accuracy of model tested using locational modeling statistics

7.

Model Evaluation

Habitat Rating	M	S	1 p(M)	2 p(S)	3 p(M S)	4 p(S M)	5 p(M S)-p(M)	6 p(S M)/P(S M')
1	27,761	0	20.91%	0.056%	0.00%	0.000%	-20.9%	0.00
2	24,105	2	18.15%	0.056%	2.67%	0.008%	-45.5%	0.12
3	70,817	43	53.33%	0.056%	57.33%	0.061%	4.0%	1.18
4	10,100	30	7.61%	0.056%	40.00%	0.297%	32.4%	8.10
Totals	132,783	75						

- $p(M)$: base rate of the model indicating an occurrence
 - 39.06% streams are less suitable
 - 60.94% streams are more suitable
- $p(S)$: base rate that an arrow darter occurrence will be found at some location
 - Calculated as the total number of occurrences divided by the total number of stream segments ($75/132,782 = 0.056\%$)
- $p(M/S)$: common calculation for model accuracy
 - 97.33% of arrow darter occurrences found in stream segments modeled favorably
 - 2.67% in stream segments modeled unfavorably
 - 0% of these in highly unsuitable segments

7.

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- $p(S/M)$: Probability of an occurrence within each of the suitability categories (compare to column 2)
- $p(M/S)-p(M)$: Improvement over chance of correctly predicting arrow darter occurrences
 - Negative % for unsuitable categories
 - Positive % for suitable categories
 - 32.4% improvement for Category 4
- $p(S/M)/p(S/M')$: Model improvement ratio; how many more times likely of an arrow darter occurrence for each category
 - 8.1 times more likely for highly suitable segments

- 40% of the independent presence data were located in the top suitability category, which only contained 7.61 percent of stream segments.
- When the model is divided into two categories of unsuitable (1-2) and suitable (3-4), appx. 60% of streams are identified as suitable.
- 97% of dace occurrences found here
- 60% of streams as suitable as overfit?
 - Arrow darter is candidate for federal protection; need for range expansion
 - Model results identify potential for suitable habitat as an avoidance measure for state transportation agencies

- Model results demonstrate this methodology's ability to identify suitable habitat
 - Simply intended to be a tool that maps an expert's knowledge of the subject
- GIS-based expert systems methodology is transferable:
 - To other aquatic species
 - Potential for terrestrial threatened and endangered species?
 - Flora and fauna?
- Methodology is transferable across disciplines:
 - Originated as a predictive model for archaeologists

Blackside Dace

Blackside Dace

Model Results

HabitatRating

Score	M	N	S	p(M)	p(S)	p(M S)	p(S M)	p(M S)-p(M)	p(S M)/P(S M')
1	176,879	176,877	2	28.49%	0.034%	0.94%	0.001%	-27.5%	0.02
2	138,361	138,347	14	22.28%	0.034%	6.57%	0.010%	-15.7%	0.25
3	164,272	164,220	52	26.46%	0.034%	24.41%	0.032%	-2.0%	0.90
4	141,428	141,283	145	22.73%	0.034%	68.08%	0.103%	45.3%	7.23