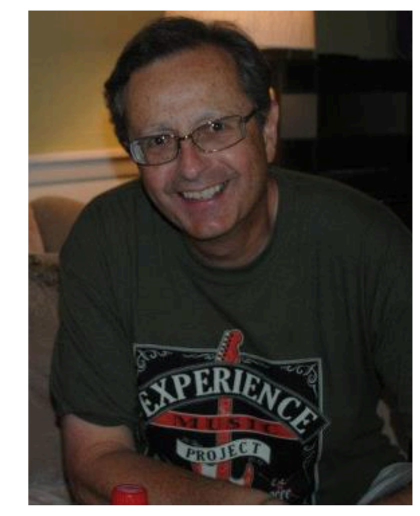
Back-Casting of Adult Striped Bass Otoliths Using a Random Forests Model to Determine Critical Coastal Nursery Habitats



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ABSTRACT

Fish species residing in the Albemarle Estuarine System (AES), a shallow wind-driven lagoonal system in North Carolina, USA, have multi-element signatures in otoliths that reflect the water chemistry of tributary rivers used as nursery habitat. We hypothesized that we could identify which watershed nursery habitats were the principal contributors to the survival and return of adult Striped Bass *Morone saxatilis* in the spawning population. Random Forests (JMP Pro 11.2) analysis was used to assign adults to their nursery habitats. The model was trained using Age 0 fish (the 2008 year class) that had known river of summer nursery habitat and known otolith elemental signatures. We then used the trained model to analyze the 60- to 120-day post-hatch region of Age 2 fish (from the 2008 year class collected in 2010) otoliths for the elemental signatures and got 100% agreement. From there, we expanded the data to include multiple year classes (1996 to 2006) found in the 2010 spawning run. Results indicated that this method can be used to back-cast adult fish to the respective nursery habitat at Age 0, and therefore determine the relative contribution of each habitat to the adult spawning population. Results can assist with selecting sites for designation as "Strategic Habitat Areas" by the state of North Carolina.

Random Forests Modelling

Random Forests, or random decision forests, is a machine learning algorithm method for classification, regression and other tasks, that operates by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees. A random decision forest corrects for the tendency of decision trees to overfit the training set. An example is shown in Fig. 1. We can model who should be expected to survive the S.S. Titanic disaster by using the ship's manifest, the cost of the fares, the sex, age, and whether there were spouses and/or siblings of survivors or those lost at sea. **Blue indicates survivors, and red indicates those that died.**

Example: Survived Titanic Passengers

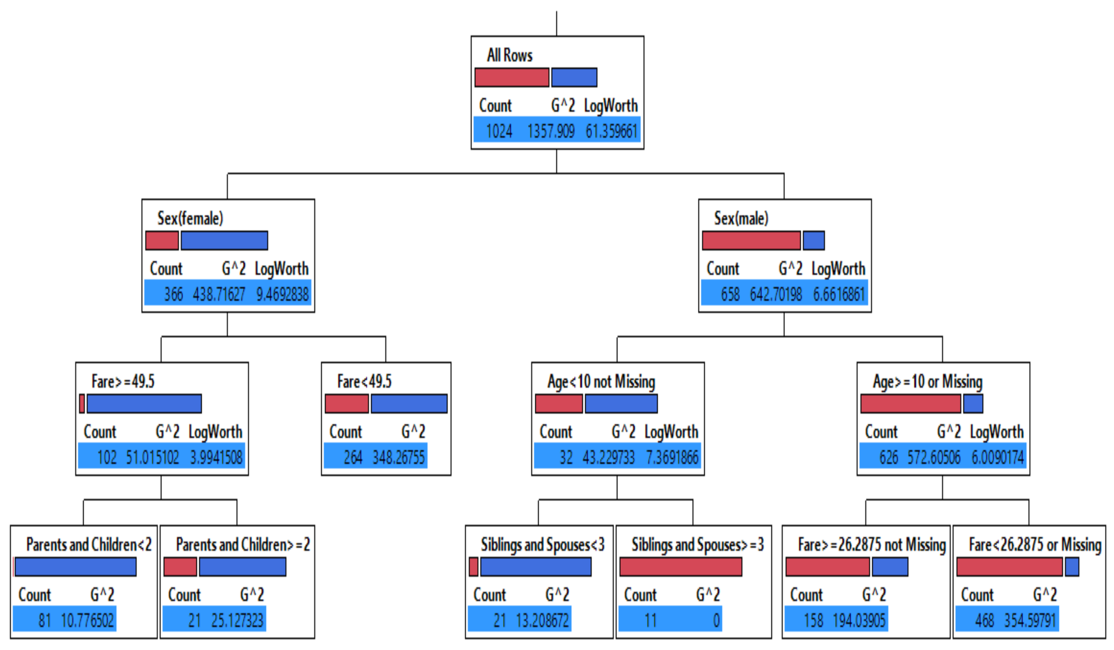

Fig. 1. Predicting the survivors of the S.S. Titanic sinking based on the ship's manifest, sex, cost of the ticket, age, and whether there were children, siblings, or spouses on board. Best survivors were those females that paid more than $ 49.50 in fare and were a parent with 1 child or no children.

METHODOLOGY

Water Chemistry

Determine spatial and temporal stability of habitat watersheds in the Albemarle Estuarine System (AES).

- Eight river systems: North River, Pasquotank River, Little River, Perquimans River, Chowan River, Roanoke River, Scuppernong River, Alligator River (Fig. 2).
- Water samples taken with peristaltic pump at the sub-surface (0.5 m), deep (0.5 m from bottom), upstream and downstream (n = 398 samples over 17 months).
- Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) used to measure strontium (Sr), barium (Ba), manganese (Mn), and magnesium (Mg).
- <u>**Spatial and temporal variability**</u> – ANOVA and Linear Discriminant Function Analysis (LDFA).

STUDY QUESTIONS

- ***Are water chemistries of the multiple Albemarle Sound watersheds stable enough to be used as "watershed fingerprints"?***
- ***If so, can otolith chemistry of <u>adult</u> Striped Bass Morone saxatilis be used to determine which <u>nursery habitats</u> contribute the most adults returning to spawn?***

Fig. 2. Map of Albemarle Sound, North Carolina, study area where white circles indicate water sample collection sites.

Fish Collections

- Adult Striped Bass collected March through May 2009 and 2010 during the pre-spawning, spawning, and post-spawn period.
- Adults sampled from spawning grounds of the Roanoke River near Weldon, North Carolina by State agency electrofishing survey.

Otolith Chemistry

- Sagittal otoliths used for ageing and micro-chemical analysis.
- LA-ICP-MS transects were used to measure Sr, Ba, Mn, Mg in Age 0 and adult otoliths (Fig. 3).
- Otolith chemistry from Age 0 fish held in cages within watersheds (Mohan et al. 2012) used to train the Random Forests model. Twenty-eight (28) predictors used. Fish classified with < 35% predictability were "unknown" to the model (e.g., fish from other river systems).
- <u>**Back-casting Adult Nursery habitats**</u> based on 60-120 days of otolith chemistry – RANDOM FORESTS

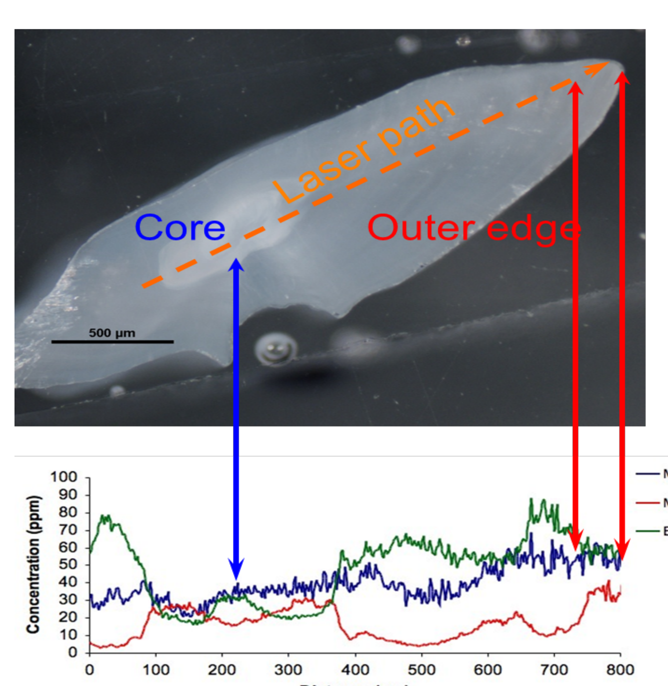

Fig 3. (Left) Laser transects from the otolith core to outer edge of Age 0 fish. <u>Nursery Habitats</u> defined as element concentrations in the section of 60 to 120 days post-hatch.

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East Carolina University

RESULTS

Water Chemistry

Watershed habitats showed <u>spatial differences</u> (ANOVA & LDFA) (Fig. 4).

Watershed habitats show <u>little temporal variability.</u>

- **Sr, Ba, Mn =** No significant variation over seasons or years.
- **Mg =** Significant short-term fluctuation.

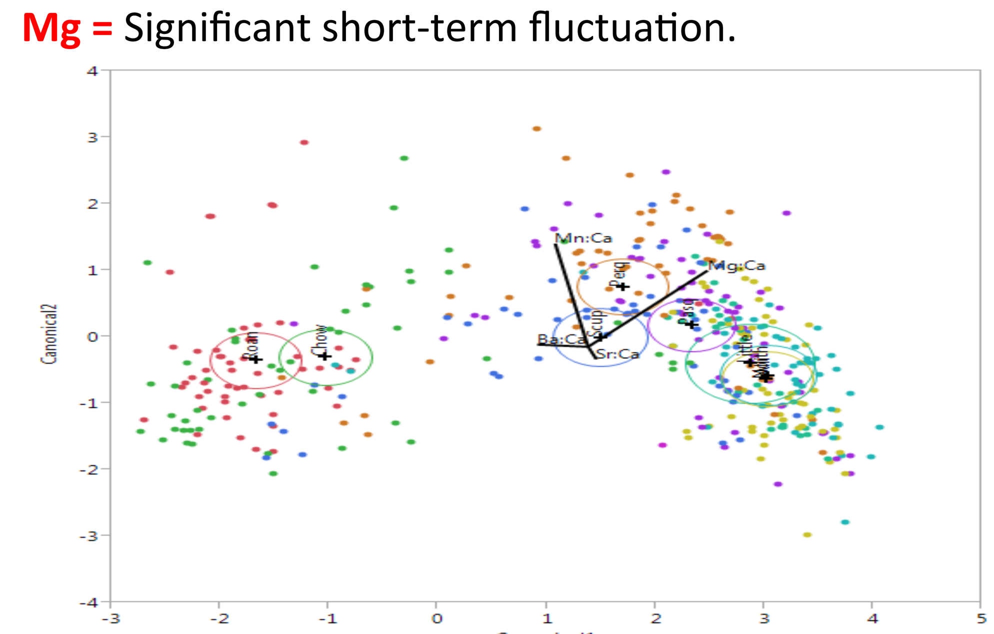

Fig. 4. LDFA of water chemistry signatures in rivers using Sr:Ca, Ba:Ca, Mn:Ca, Mg:Ca ratios in water samples (n=398) collected from October 2010 to July 2012. Group circles = 95% confidence limit.

Otolith Chemistry

- The Chowan (CHOW), Perquimans (PERQ), & Pasquotank (PASQ) rivers were where most spawning adults had spent their first summers of life.
- Habitat signatures were:
- Perquimans River – high Mn (Fig. 5) & <u>most returning fish as adults</u> (Table 1).
- Chowan River – low Sr & high Ba; second most returning adult fish.
- Pasquotank River – high Sr, low Ba, & high Mg (Fig. 5).

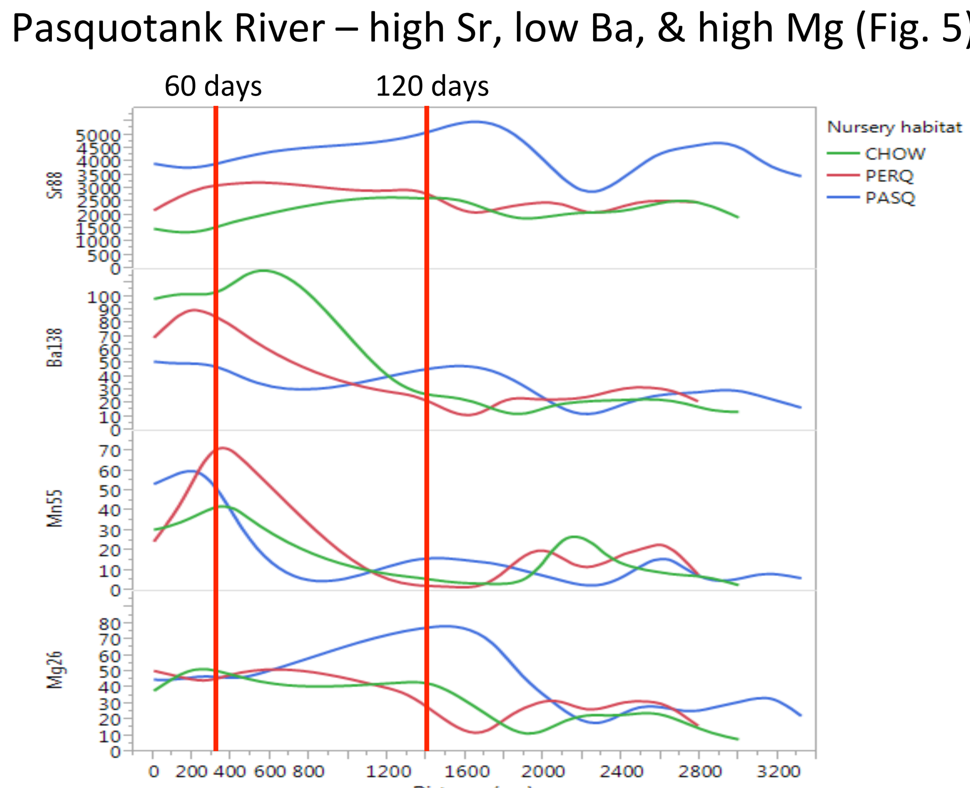

Fig. 5. Differences of the four trace elements in otoliths from adults using nursery habitats in the three important watersheds: Chowan, Perquimans, and Pasquotank rivers between 60 and 120 days (Hughes 2008 year class data).

Table 1. Datasets modeled from Mohan's 2008 year class compared to 60 to 120 days of Hughes' 2008 year class, Hughes' 2007 year class, and Hughes' 2006 to 1994 year class. Table shows total number of fish, number of fish predicted to each river, and percentage of fish predicted to each river. (ALLI=Alligator River, CHOW=Chowan River, PASQ=Pasquotank River, PERQ=Perquimans River, UNKN=Unknown River).

Dataset Modeled	Total N	ALLI N	ALLI %	CHOW N	CHOW %	PASQ N	PASQ %	PERQ N	PERQ %	UNKN N	UNKN %
Mohan (2008 YC)	14	1	7.14%	3	21.43%	3	21.43%	7	50.00%	0	0.00%
Hughes (2008 YC)	17	0	0.00%	3	17.65%	1	5.88%	13	76.47%	0	0.00%
Hughes (2007 YC)	23	0	0.00%	7	30.43%	0	0.00%	14	60.87%	2	8.70%
Hughes (2006 to 1994 Year Classes)	206	0	0.00%	25	12.14%	6	2.91%	142	68.93%	33	16.02%

CONCLUSIONS

- The Random Forests model works extremely well to detect patterns in otolith chemical signatures and matches them to known habitats.
- Researchers must first determine stability of habitat water chemistry to ensure that young fish inhabiting that habitat will acquire a signature characteristic of that habitat.
- Anthropogenic influences (farming, urban) can be used as predictors in the model.
- The Perquimans River is the most important nursery habitat for Striped Bass to survive to adulthood.

Mohan, J.E., R.A. Rulifson, D.R. Corbett, and N.M. Halden. 2012. Validation of oligohaline elemental otolith signatures of striped bass using in situ caging experiments and water chemistry. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 4(1):57-70.