REPORT FOR THE NMFS RIVER HERRING STOCK STRUCTURE WORKING GROUP

Population genetic structure in anadromous river herring: Implications for proposed listing under the US Endangered Species Act

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Objectives:

1)assess genetic differentiation among spawning runs

2)assess higher-level population structure

3)investigate the effect of geography on variation in genetic divergence

Approach:

• we deployed 15 novel microsatellite markers on samples collected from across the USA ranges of both species

• genotyped a total of 778 alewife samples from 15 rivers spanning the alewife range from Maine to North Carolina.

• genotyped a total of 1,201 blueback herring samples from 20 rivers spanning the blueback herring range from Maine to Florida.

Funding was provided by the National Fish and Wildlife Foundation under its River Herring Initiative.

Table 1: Number of specimens (N) genotyped per species by river.

River	State	Alewife (N)	Blueback (N)
East Machias (EMAC)	ME	59	58
St. George (STGEO)	ME	65	50
Lamprey (LAM)	NH	47	0
Exeter (EX)	NH	0	41
Mystic (MYST)	MA	69	69
Town Brook (TBRO)	MA	49	0
Monument (MON)	MA	46	51
Gilbert Stuart (GIL)	RI	44	38
Connecticut (CON)	CT	37	138
Hudson (HUD)	NY	61	79
Delaware (DEL)	NJ	47	49
Nanticoke (NAN)	MD	39	24
Rappahannock (RAP)	VA	62	58
James (JAM)	VA	0	98
Chowan (CHOW)	NC	54	72
Roanoke (ROA)	NC	50	50
Alligator (ALL)	NC	49	0
Neuse (NEU)	NC	**	65
Cape Fear (CF)	NC	**	57
Santee (SAN)	SC	NA	62
Savannah (SAV)	GA	NA	52
Altamaha (ALT)	GA	NA	53
St. Johns (SJR)	FL	NA	37

** possibly extirpated

RESULTS

Genetic differentiation:

1. natal homing behavior in both alewife and blueback herring has caused significant genetic differentiation among the majority of spawning runs sampled. Genetic differences among alewife and blueback herring spawning runs is generally larger than those observed for American shad, particularly in the US portion of the American shad range.

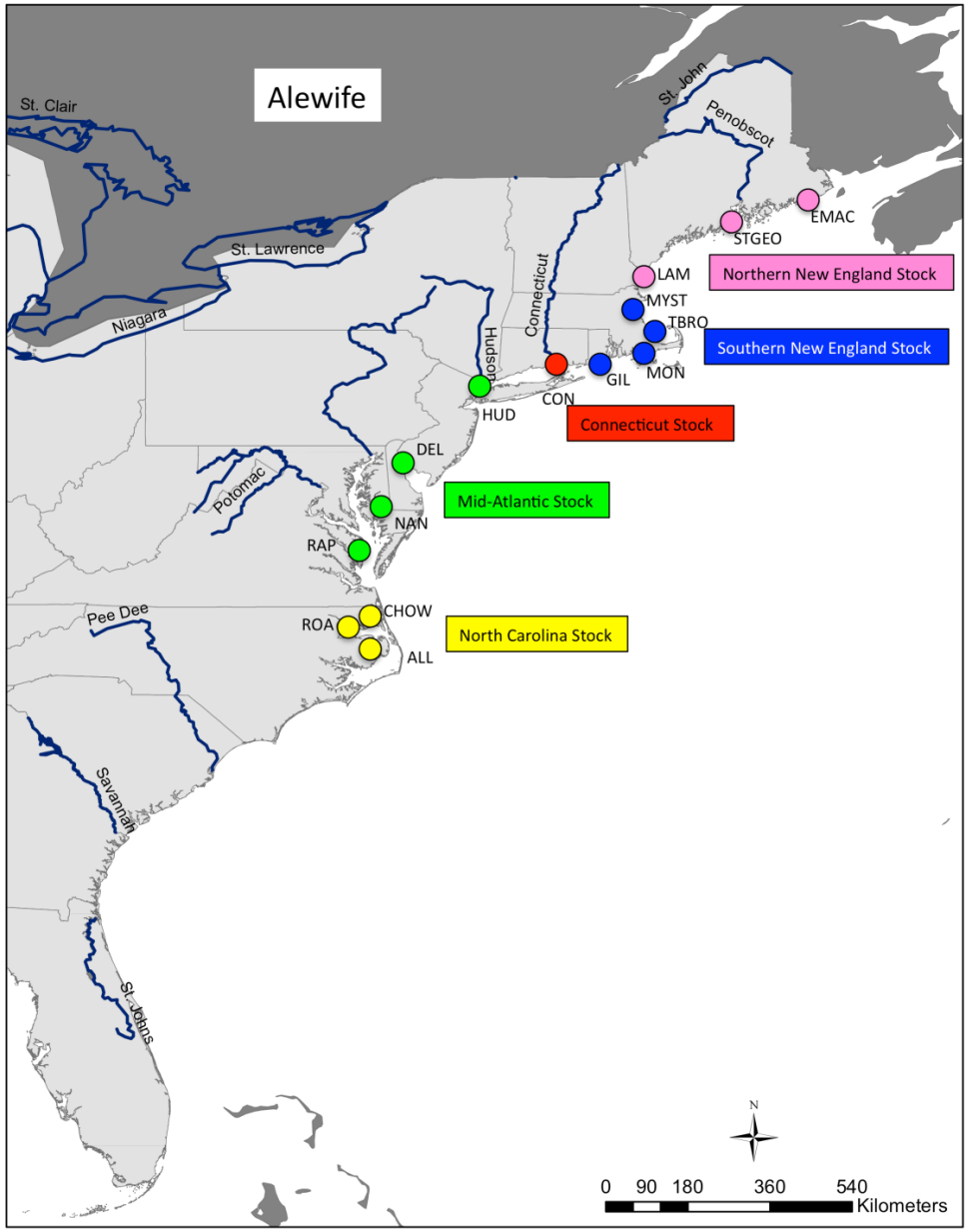
Higher-level population structure:

Results from Bayesian clustering methods indicate the presence of higher-level genetic structure within the alewife and blueback herring ranges in the USA. This higher-level genetic structure can be considered analogous to stock complexes, as used in previous studies to identify ‘distinct population segments’.

Alewife

1. We infer the presence of a minimum of 5 genetically distinguishable stocks in alewife (Fig. 1). These alewife stocks correspond to (1) a Northern New England Stock [East Machias River, St. George River, Lamprey River], (2) a Southern New England Stock [Mystic River, Town Brook, Monument River, and Gilbert Stuart River], (3) a Connecticut Stock [Connecticut River], (4) a Mid-Atlantic Stock [Hudson River, Delaware River, Nanticoke River, Rappahannock River], and (5) a North Carolina Stock [Chowan River, Roanoake River, Alligator River].

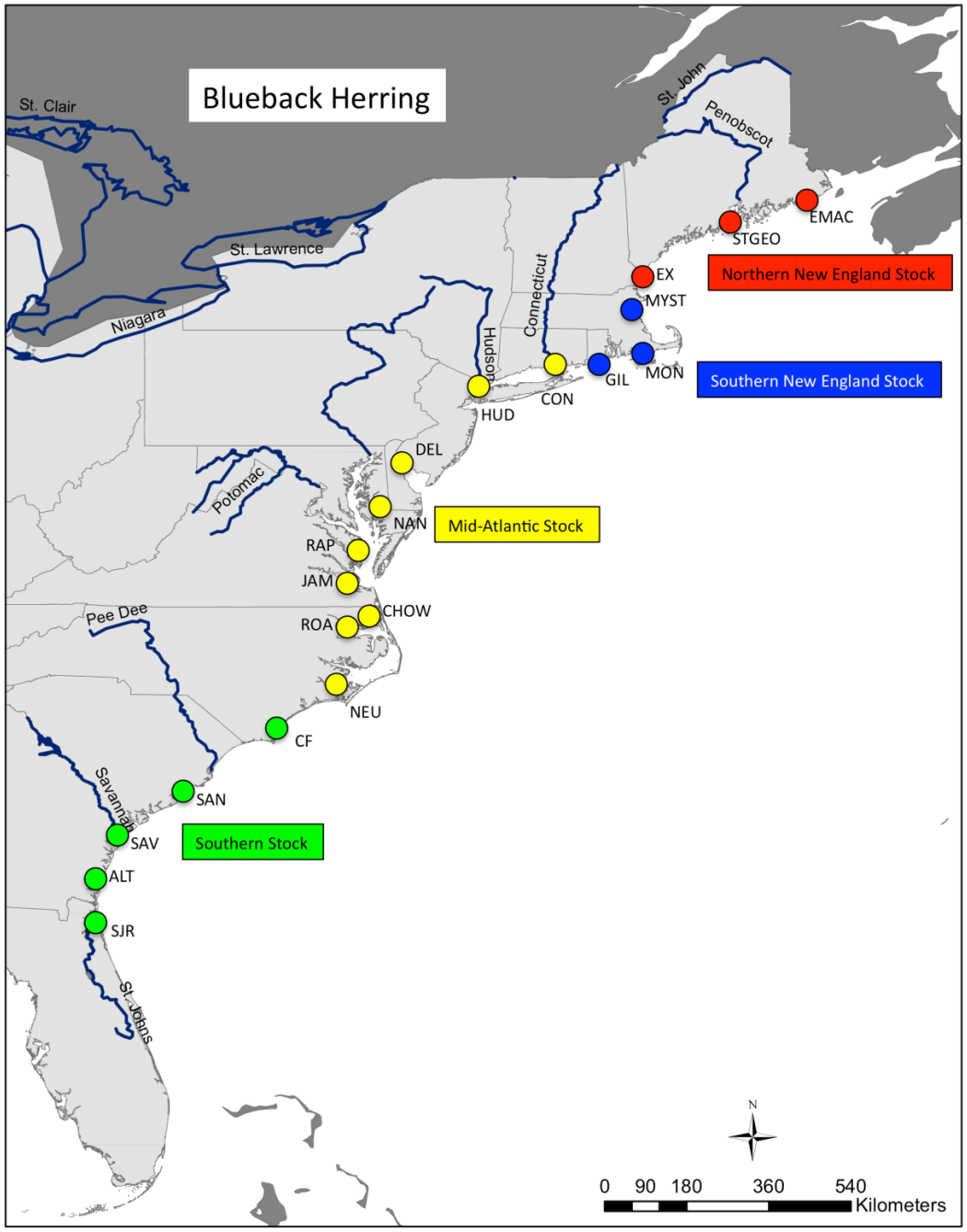
Fig. 1: Proposed stock structure in alewife identified using the Bayesian clustering algorithm implemented in BAPS v.5.1 (Corander et al. 2006)**.** The Connecticut Stock is the only stock in either species to be defined by a single river and, therefore, should be treated as tentative until further analyses can be performed.



Blueback herring

1. We infer the presence of a minimum of 4 genetically distinguishable stocks in blueback herring (Fig. 2). These blueback herring stocks correspond to (1) a Northern New England Stock [East Machias River, St. George River, Exeter River], (2) a Southern New England Stock [Mystic River, Monument River, Gilbert Stuart River], (3) a Mid-Atlantic Stock [Connecticut River, Hudson River, Delaware River, Nanticoke River, Rappahannock River, James River, Chowan River, Roanoake River, Neuse River], and (4) a Southern Stock [Cape Fear River, Santee River, Savanah River, Altamaha River, and St. Johns River].

Fig. 2: Proposed stock structure in blueback herring identified using the Bayesian clustering algorithm implemented in BAPS v.5.1 (Corander et al. 2006).



Effect of geography:

1. a strong effect of latitude of genetic divergence suggesting that, although most populations are genetically differentiated, gene flow is greater among neighboring runs than among distant runs.

2. This effect was especially strong in alewife, where latitude explained 92% of the variation.

3. In blueback herring, latitude explained 85% of the variation.

Conclusions:

1. significant differentiation among alewife and blueback herring spawning runs in most cases, suggesting that the major river drainage is the appropriate level of management for these species. [This result supports the findings of the ASMFC Stock Assessment, which found a lack of correlation for population trends in neighboring runs (ASMFC 2012).]

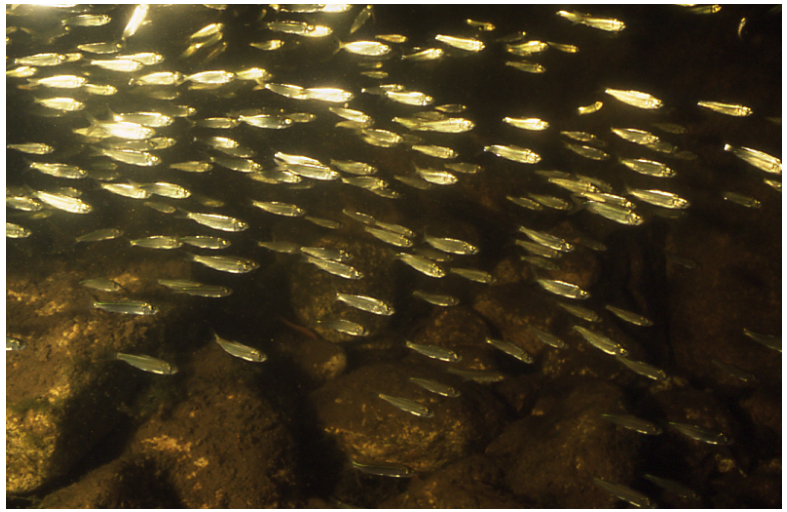
2. in some cases we did not find significant genetic divergence among neighboring rivers. This result suggests that straying among neighboring watersheds has led to some degree of homogenizing gene flow, but within larger-scale geographic boundaries.

3. gene flow is not continuous across all parts of the species' ranges. There are geographic breaks in gene flow that should be recognized, as they represent the major sources of genetic variation.

4. The location of these larger-scale geographic boundaries to gene flow (i.e., across which gene flow is extremely minimal) is what defines the higher-level population structure or stock structure. There is a high level of agreement between what the analyses identify as regions of gene flow and what clustering methods identify as genetically distinguishable stocks. Thus, we have good confidence that we have identified at least the major genetic stocks for alewife and blueback herring in the USA portions of the species' ranges.

5. Importantly, these breaks in gene flow are not the same in alewife and blueback herring. Both species show congruent Northern New England Stocks (ME, NH) and Southern New England Stocks (MA, RI). However, the Connecticut River is tentatively identified as a unique Connecticut Stock in alewife, whereas it is grouped with the Mid-Atlantic Stock in blueback herring. Likewise, the Chowan River, Roanoke River and Alligator River form a distinct North Carolina Stock in alewife, whereas these rivers, plus the Neuse River, are part of the Mid-Atlantic Stock in blueback herring.

6. We were unable to collect samples of alewife in southern streams (SC & NC) where the species had been found. **Alewife appears to be experiencing a range contraction** at the southern end of its distribution, with populations extirpated from South Carolina, and now possibly extirpated from southern North Carolina.

Future Work for our project:

1. Conduct additional quality control checks on our data, including investigating the evidence of hybridization in all river samples.
2. Finish analyzing additional samples at the lab. Some of the last samples from this year's runs in New England just arrived in the lab and we didn't have time to finish them. Results are expected by late summer/early fall.
3. Determine if new results shed light on the Connecticut River alewife stock issues. We have samples from other Long Island Sound (CT) streams.
4. Explore the use of this data set to identify the origin of fish captured at sea.