Appendix A

Expert Opinions from the River Herring Stock Structure Workshop

June 20-22, 2012

Stock Structure Workshop Expert Opinion- Mike Armstrong (Massachusetts Department of Marine Fisheries)

The information presented was very helpful in moving forward our understanding of river herring stock structure, but also illustrated the lack of data particularly for the southern part of the range. It is clear that differences in genetics and demographics, resulting from natal homing, indicate that the fine scale management of individual rivers/systems is necessary. However, a broader scale is needed when we consider stock structure for larger management tools such as the ESA listing. I believe that the genetic data gives us the best indication of stock structure. The genetics indicate a higher level structure of several units for both species. The maps presented for both species (from Eric's genetic work) are very similar to what I came into the meeting with as a strawman based on my knowledge of run demographics, population dynamics, and trends in run abundance. I feel these should move forward as our best estimate of stock structure (and perhaps dps's). There remains some uncertainty, especially in regards to alewives in the CT River and surrounding areas. The other point that became clear from the workshop is that bluebacks have demonstrated clearly different patterns of abundance than alewives, and are likely at lower abundance.

Review of River Herring (Alewife and Blueback herring) information for stock structure

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July 6, 2012

A review of the existing literature, including some recent white papers was requested to aid in determination of stock structure for river herring: alewife and blueback herring. Determination of stock structure, per the request, was to identify how individual population should be grouped (if appropriate), reflecting similar genetic, behavioral, demographic, other trait which could indicate that populations are related or interact, and therefore should be managed as a single unit. For purposes of this discussion, the use of a "population" references an entire river drainage and all of the alewife or blueback herring contained within.

References were provided to participants to assess stock structure, including presentation materials from non-published research. Although references related to ocean migrations and seasonal distributions of both species within the marine environment were presented, overall information which could be used to infer stock structure and define population relationships was limited, and therefore this review will focus on an analysis of the genetic results presented. Life history Information which could be useful to determine stock structure would include tagging studies linking individual populations to seasonal or annual migrations to a common area (e.g. the marine distribution for both species), evaluation of life history parameters on a population-specific scale using consistent metrics and measurements, population specific straying and return information to natal rivers (or to other locations for spawning), or other similar studies which could provide an understanding about population interactions and differences.

Of the information presented, the most useful data which could be used to infer stock structure were the two genetics reports (Palkovacs et al. 2012 and Willis et al. 2012). Palkovacs et al. (2012) presented range-wide genetic data for both alewife and blueback herring, and was able to identify a minimum of five genetically distinguishable stocks for alewife and a minimum of four genetically distinguishable stocks for blueback herring. These results however were preliminary, and need further analysis to determine if the proposed structure adequately reflects stock structure for both species. Results of genetic differences between each river (F_{ST} and θ) indicate a high amount of population differentiation, indicating little gene flow between drainage for the populations sampled. Although results were not included in the report, the authors mentioned the use of PCA analysis which detected a correlation between geographic and genetic distance, however it was not mentioned which for species this result pertained. Correlation of genetic and geographic distance supports the F_{ST} and θ results and inference of limited overall gene flow, but when gene flow occurs, it is more likely to occur with neighboring populations, as supported by Palkovacs et al. (2008). These correlations support management of geographically proximate populations as a group, rather than on an individual

population basis. If additional population were incorporated into this analysis, a more pronounced genetic signature of straying may exist for populations at a closer geographic distance.

Stock structure in Palkovacs (et al. 2012) was inferred using both STRUCTURE (Pritchard et al. 2000, Falush et al. 2003) and BAPS v 5.1. (Corander et al. 2006). For alewife, congruence between the BAPS results and STRUCTURE (delta K method) identified five genetically identifiable stocks, but for blueback herring, an optimum solution was not identified using STRUCTURE and stock structure results relied only on BAPS results, which identified four genetically identifiable stocks. Although these Bayesian-based methods are powerful analytical tools, use of additional genetic analyses and alternate data (such as life history information) to support the proposed clustering of populations into stock groups would be helpful. Most importantly, inclusion of additional information and analysis of samples at a range of temporal scales would also be useful to know if genetic differences exist within runs, between year classes, or between sampling years, as these parameters may impact the observed levels of population differentiation and therefore the stock structure proposed.

Limitations to the interpretation of the results for both species in Palkovacs (et al. 2012) include small sample sizes, range-wide but coarse sampling, and little to no information about sampling methods such as sample year, the sampling period within the returning spawning run being sampled, or if samples represent multiple age classes. The addition of repeat sampling over multiple years (and age classes) for at least a few populations would be useful to assess temporal stability of the observed genetic differences. This last component may be accomplished through determining the age composition of the sampled individuals, although this would require scale reading and likely increasing the number of samples analyzed within a given river system to adequately sample each year class.

Information presented by Willis et al. (2012) was specifically for alewife and limited primarily to genetic comparisons among populations in Maine. In contrast to the geographic distribution of samples in Palkovacs et al., the geographic distribution of sampling in Willis et al. (2012) was at a finer scale, with sampling focused on most river systems within Maine that contained alewife, and included a sample from the Nemasket River in Massachusetts. Willis et al. (2012) identified three clusters of populations using BAPS, however when a principle component analysis (PCA) of pairwise F_{ST} compared Maine populations to populations in Canada, the previously observed structure disappeared and the majority of the Maine populations grouped together. However, it did not appear that all populations from the Willis et al. (2012) analysis were included in the comparison with Canadian alewife populations.

As an outlier, Willis et al. (2012) included genetic samples from the Nemasket River in Massachusetts, from what would be identified by Palkovacs et al. as the Southern New England stock. The differentiation of the Nemasket River population from the Maine populations (Northern New England stock) was supported through the population clusters identified by BAPS, however this outlier population was not included in the PCA with the Canadian populations, so it is unknown if this differentiation between two of the proposed stocks would be supported when included with populations from a larger geographic distribution. The change in population structure between BAPS analysis of the Maine populations and PCA comparison with Canadian populations in Willis et al. (2012) highlights how population structure may be biased according to which populations are included or

excluded from the analysis. General estimates of genetic diversity, individual pairwise values of F_{ST}, and sampling information (such as sample size, year sampled, the duration of sampling during the spawning run, or temporal comparison of samples across years) were not provided.

Findings presented in Willis et al. (2012) preliminarily support those of Palkovacs et al. (2012) related to differentiation between the proposed Northern New England and Southern New England stocks of alewife, however further analyses are warranted to confirm this delineation. In addition, findings at the local scale within Willis et al. (2012) and Palkovacs et al. (2008) support that when gene flow occurs within alewife populations, it likely occurs very locally among neighboring populations, supporting a regionally-based stock structure, opposed to a structure based on individual river systems. Localized gene flow is also consistent with the large genetic differentiation observed between populations sampled in Palkovacs et al. (2012).

Of the literature provided for the stock structure review, the most useful information available to infer population relationships for alewives and blueback herring was provided in Palkovacs et al. (2012), although the analysis appears to be preliminary and additional samples remain to be analyzed. Initial delineation between a Northern and Southern New England stock for alewives was supported preliminarily by Willis et al. (2012), although those results also appear preliminary. Additional information regarding sampling methods for both papers, analysis of additional samples to increase sample size, understanding of the temporal stability of genetic structure both within a run and across year classes, and resolution of potential hybridization issues is warranted to improve interpretation of the data. Although information regarding the seasonal distribution and abundance of both species in the marine environment was presented, the ability to directly link these patterns to specific populations was limited, and therefore did not allow clear inferences to stock structure. Life history information reviewed in the ASMFC (2012) identified stock structure for river herring could occur either at the river or regional scale, of which the genetic results to date support the regional scale (Palkovacs et al. 2008, 2012, Willis et al. 2012). However, accurate identification of the regional boundaries would benefit from completion of the genetic analyses as discussed in Palkovacs et al. (2012).

References

ASMFC. 2012. River Herring Benchmark Stock Assessment Volume I. Stock Assessment Report No. 12-02 of the Atlantic States Marine Fisheries Commission.

Corander, J. P. Marttinen, and S. Matyniemi. 2006. A Bayesian method for identification of stock mixtures from molecular marker data. Fishery Bulletin 104: 550-558.

Falush, D., M. Stephens, and J.K. Pritchard. 2003. Inference of population structure using multilocus genotype data: linked loci and correlated allele frequencies. Genetics 164: 1567-1587.

Palkovacs, E.P., K.B. Dion, D. M. Post, and A. Daccone. 2008. Independent evolutionary origins of landlocked alewife populations and rapid parallel evolution of phenotypic traits. Molecular Ecology 17: 582-597.

Palkovacks, E.P, E.E. Argo, D.J. Hasselman, T.F. Schultz, E.M. Labbe, T.V. Willis, K.E. Limburg, S.M. Turner, S.R. Gephard, D.M. Post, and S. R. Thorrold. 2012. Report for the NMFS River Herring Stock Structure Working Group. June 1, 2012.

Willis, T.E. 2012. Alewife (*Alosa pseudoharengus*) stock structure north of Cape Cod. June 1, 2012. Presentation to the NMFS River Herring Stock Structure Working Group.

Stock Structure Workshop Expert Opinion- Matt Cieri (Maine Department of Marine Resources)

1) Given the genetic similarities and straying among adjacent river systems it seems clear that having the DPS's being river-by river isn't practical or warranted.

2) Given the fact that there are differences in abundance trends and genetic structure by region that treating this as one DPS unit would likewise be untenable. This is particularly in light of the fact that some regions may contain genetic traits, which, if allowed to go extinct would reduce overall genetic diversity and fitness of the species…both blue backs and alewives.

3) This suggests that a regional DPS system should be implemented. While the options we discussed under this approach are ok, the one listed in the petition doesn't see biologically based.

Stock Structure in River Herring (Alewife, *Alosa pseudoharengus,* and Blueback Herring, *Alosa aestivalis*) on the Atlantic Coast

Katie Drew
Atlantic States Marine Fisheries Commission
June 29, 2012

The best available genetic data suggest there is structure within the coastwide populations of alewife and blueback herring, at both the river level and at a regional level. Genetic results are consistent with our understanding of river herring life history: they return to natal rivers to spawn, but do not exhibit complete site fidelity. The genetic work suggests straying is more likely to occur within a region than between regions. This is not to say regions are biologically homogeneous. Genetic differences were detectable between most rivers tested. This is consistent with results of the recent ASMFC stock assessment, which noted that even among rivers within the same state, there could be differences in trends in abundance indices, size-at-age, age structure, species composition, and other metrics, indicating there are localized factors affecting the population dynamics of both species.

River herring stock structure is complicated by our lack of knowledge about population structure at sea. It is often pointed out the name "river herring" is apt only in comparison to sea herring – alewife and blueback herring spend the majority of their lives in the ocean. Limited tagging data suggest they are capable of long migrations, with blueback herring tagged in the Bay of Fundy being recaptured in Maryland and North Carolina. Survey catches of river herring are more evenly distributed across the continental shelf in spring, and concentrated in more northern areas such as the Gulf of Maine, Georges Bank, and Canadian waters during the summer, fall, and winter. This suggests the coastwide population as a whole migrates up and down the coast. Whether river herring in the ocean cluster with their river or regional stocks, or whether the river stocks mix completely at sea has not been determined yet.

Our understanding of river herring stock structure may be refined by on-going research that will add genetic data from rivers on a finer geographical scale and from ocean catches.

Stock Structure Workshop Expert Opinion- Steve Gephard (Connecticut Department of Energy and Environmental Protection)

My recommendations are reflected in the presentation I gave. I'll make two comments:

1. I think the Connecticut River stock complex, as identified by our paper, should be called the "Long Island Sound" stock complex (or DPS) and include all streams flowing into Long Island Sound between the Byram River (CT-NY border) to the west and the Pawcatuck River (CT-RI border to the east (inclusive) because I believe our additional data, available later this summer will show that other CT tributaries to LIS will cluster with the Connecticut River. If I'm wrong, names can be adjusted later.

2. I think the "North Carolina" stock of alewife, as identified in our paper, should be called the "Carolina" stock complex (or DPS) and include the North Carolina streams as shown in our Figure 1 but also include all streams farther south in North Carolina and South Carolina (to southernmost stream of the historical range) known to host alewife runs in the past but could not be sampled for our study because the fish could not be found.

Expert opinion on stock structure of alewives and blueback herring

Dr. Adrian Jordaan

School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY.

I would like to contribute details to 3 aspects of stock structure of alewives, *Alosa pseudoharengus,* and blueback herring, *Alosa aestivalis*. The first regards the movements of both species during oceanic migrations. Second, there have been significant changes in populations due to historical landscape changes that are likely to have homogenized populations. Third, given the genetic data and straying rates, as well as the results of genetic analyses, I advocate a conservative application of distinct population segments.

Ocean migrations

The work of Nevis (1981) and Stone and Jessop (1992) provide the best guidance regarding oceanic distributions of both river herring species. While many uncertainties exist regarding the distributions of both species due to lack of data, some generalizations can be made.

Both species appear to overwintering in temperatures between 4 and 7°C (Nevis 1981), perhaps keying on an optimal temperature of 5°C (Stone and Jessop 1992). However, movements amongst summer feeding grounds in the coastal zone, for example the Bay of Fundy, and overwintering grounds identified as a deep area on the Scotian Shelf and a broad region covering US waters between the shelf break and land from Cape Hatteras into the Gulf of Maine, mean that both species occupy broad marine distributions.

Tagging results from a 1980s study (Rulifson et al. 1987) suggested that blueback herring captured during the summer in the Bay of Fundy generally moved southward as far as South Carolina and Maryland. Tagged alewives, in contrast, were captured primarily in Nova Scotia weir fisheries and only as far south as Massachusetts. Thus, a general pattern of northerly winter movements for alewives and a southerly movement for blueback herring could be inferred. This also suggests that the freshwater-based more southerly/warmer distribution of blueback herring may be maintained in overwintering distributions.

Recent work also suggests that Gulf of Maine alewives have not experienced the same declines as more southerly populations (Armstrong Expert testimony; ASMFC 2012; Jordaan and Kritzer, In prep). A posssible explanation is that the southerly hotspots of bycatch identified (Cieri Expert Testimony; Cournane et al. In Review) clustered between Cape Cod and the New York Bight may have greater impact on blueback. Bycatch-related declines may not impact Gulf of Maine populations of alewife if their migration directs fish into Canadian waters off Nova Scotia.

Regardless of movements, the coastal ocean represents a mixed stock of river herring species. The mixing zone is seasonally based, shifting from inshore waters during the summer to more offshore distributions in the winter. However, it also appears that river herring, juveniles in particular, can maintain nearshore distributions during the winter as well. As a result, while recognizing that some marine structuring may exist and that this is a critical research area, current information can only unequivocally say that both river herring species exist as a well mixed stock in the ocean while not in freshwater spawning runs. Further, the large migratory distances means that stocks far removed from their spawning area may be susceptible to a variety of fisheries impacts as are sturgeon (Dunton et al. 2011).

Historical declines

While the status of Maine-based populations appears to be better that that of more southerly stocks, the region has undergone dramatic losses in freshwater range. The fracturing of habitat through historical damming reduced the potential habitat available to alewives by 95% by 1850 (Hall et al. 2011). This loss also accompanied a shift in fisheries productivity from large inland watershed to small coastal watersheds (Hall et al. In Press). While microstructure (river-specific) stocks likely existed in the past, this loss of habitat combined with stocking programs has led to a homogenization of genetic populations and likely contributes to the ~100km scale of structuring determined by genetic data (Willis Expert Testimony, Palkovacs/Gephardt Expert Testimony).

Straying, stocking and stock boundaries

In addition to a high degree of natal homing, straying rates are estimated at around 20% (Gahagan et al. 2012). It appears that most straying is confined to adjacent rivers (Rulifson, Unpub. data). However, there is not enough data to definitively identify boundaries to straying across the species' ranges. Further, spawning habitat loss and damming may have encouraged the survival of straying phenotypes. Thus, while the preliminary genetic data supports a general pattern of stock structure that includes 4-5 distinct population segments, delineating strict boundaries for stock regions is not as clear. The alewife stock structure based on the testimony of Palkovacs/Gephardt identified the Connecticut River as distinct from the remainder of the East coast populations tested. However, no other rivers from the region were available and thus there is no way to define the limits of this distinct population segment. Because of this, I suggest that the Long Island Sound region be included in the mid-Atlantic region for alewife stock structuring. Furthermore, this allows the 2 species to have similar tock structuring but also maintains flexibility for future genetic results to allow 2 sub-stocks without having to re-draw distinct population segment boundaries. Combining the two most southerly stocks would allow complete overlap in the two species stock boundaries.

Conclusions

I advocate 4 separate US stocks (and 3 Canadian stocks) for alewives: Southern stock (North Carolina), Mid-Atlantic (from North Carolina to Connecticut-Rhode Island border), New

England (Rhode Island to New Hampshire-Maine border) and Central Gulf of Maine (Maine-New Hampshire border to Canadian border). For blueback herring, the same designations hold except the southern stock ranges from Florida to South Carolina-North Carolina border and the Mid Atlantic stock ranges from North Carolina to Connecticut-Rhode Island border (see attached maps).

It is critical to acknowledge a substantial and generally uncharacterized ocean mixed stock occurs. Thus, despite the vast differences in life history, any DPS delineation will share many characteristics with the recently listed Atlantic sturgeon: coast-wide structuring with a large mixed stock region in the ocean. A major issue with the genetic data is the lack of coverage, and the resulting uncertainty regarding the boundaries of any stock.

It is also important to note that structuring is supported partially by population trajectories for alewives, but consistent coast-wide declines of blueback herring contrast any finer scale structuring and indicate that a common driver(s) appears to be affecting the whole species range.

References

ASMFC. 2012. Terms of Reference & Advisory Report to the River Herring Stock Assessment Peer Review. Limburg, K.E., Oliveira, K., Wiedenmann, J., O'Boyle, B. Stock Assessment Report No. 12-02 of the Atlantic States Marine Fisheries Commission. Arlington, VA.

Cournane, J.M., Correia, S.J. and J.P. Kritzer. In Review. A spatially-explicit model of river herring hotspots at sea.

Dunton, K.J., D. Chapman, A. Jordaan, K. Feldheim, S. O'Leary, K.A. McKown and M.G. Frisk. 2012. Genetic mixed-stock analysis of Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* in a heavily exploited marine habitat indicates the need for routine genetic monitoring. Journal of Fish Biology 80(1): 207-217.

Gahagan, B.I., Vokoun, J.C., Whitledge, G.W. and E.T. Schultz (2012). Evaluation of Otolith Microchemistry for Identifying Natal Origin of Anadromous River Herring in Connecticut. Marine and Coastal Fisheries 4(1): 358-372.

Hall, C.J., Jordaan, A. and M.G. Frisk. 2011. The historical influence of dams on diadromous fish habitat with a focus on river herring and hydrologic longitudinal connectivity. Landscape Ecology 26(1): 95-107.

Hall, C.J., Jordaan, A. and M.G. Frisk. In Press. Centuries of anadromous forage fish loss: consequences for ecosystem connectivity and productivity. Bioscience (anticipated in August issue).

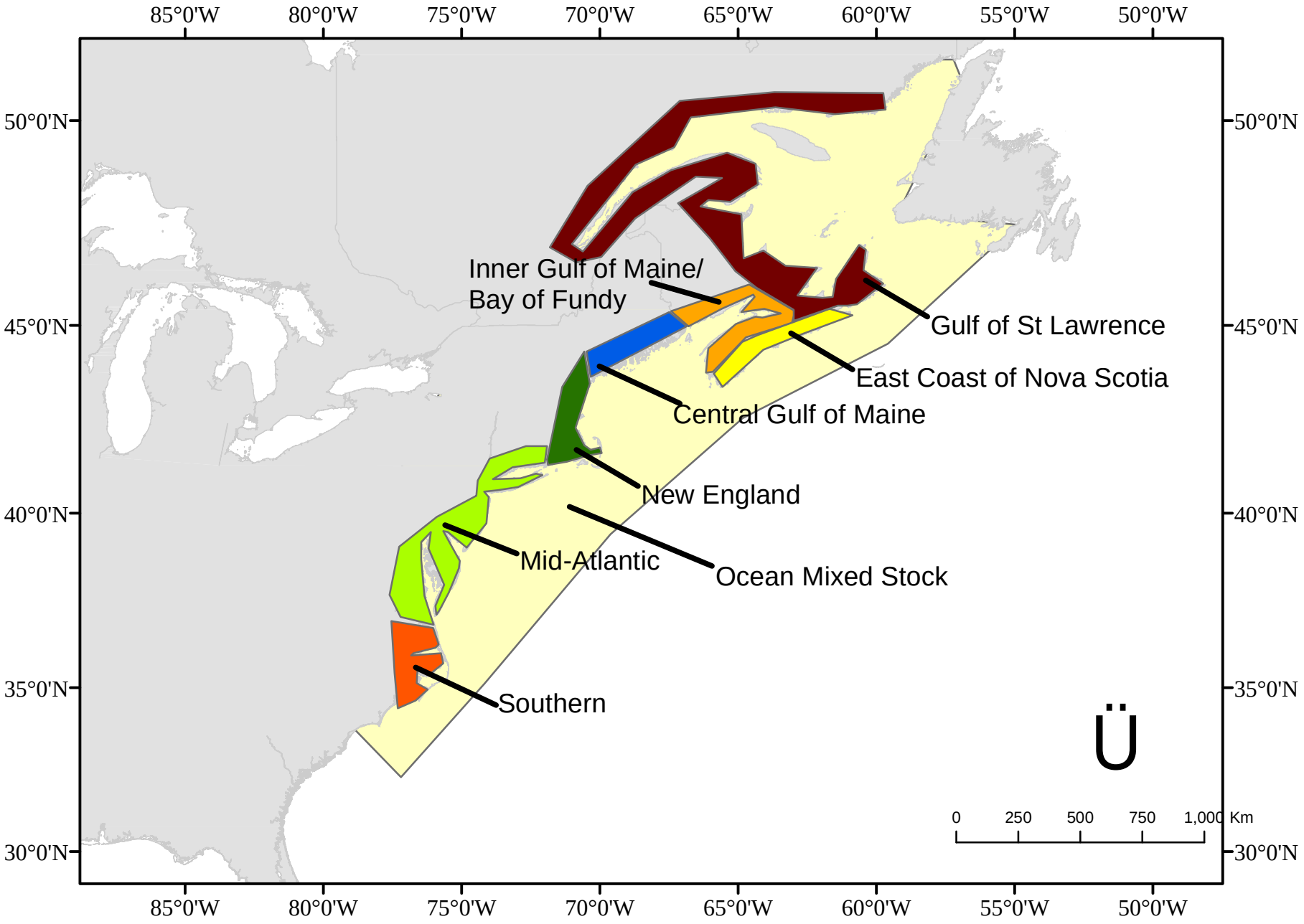
Jordaan, A. and J.P. Kritzer. In Prep. Oceanographic, watershed and anthropogenic drivers of river herring productivity: identification of restoration impediments.

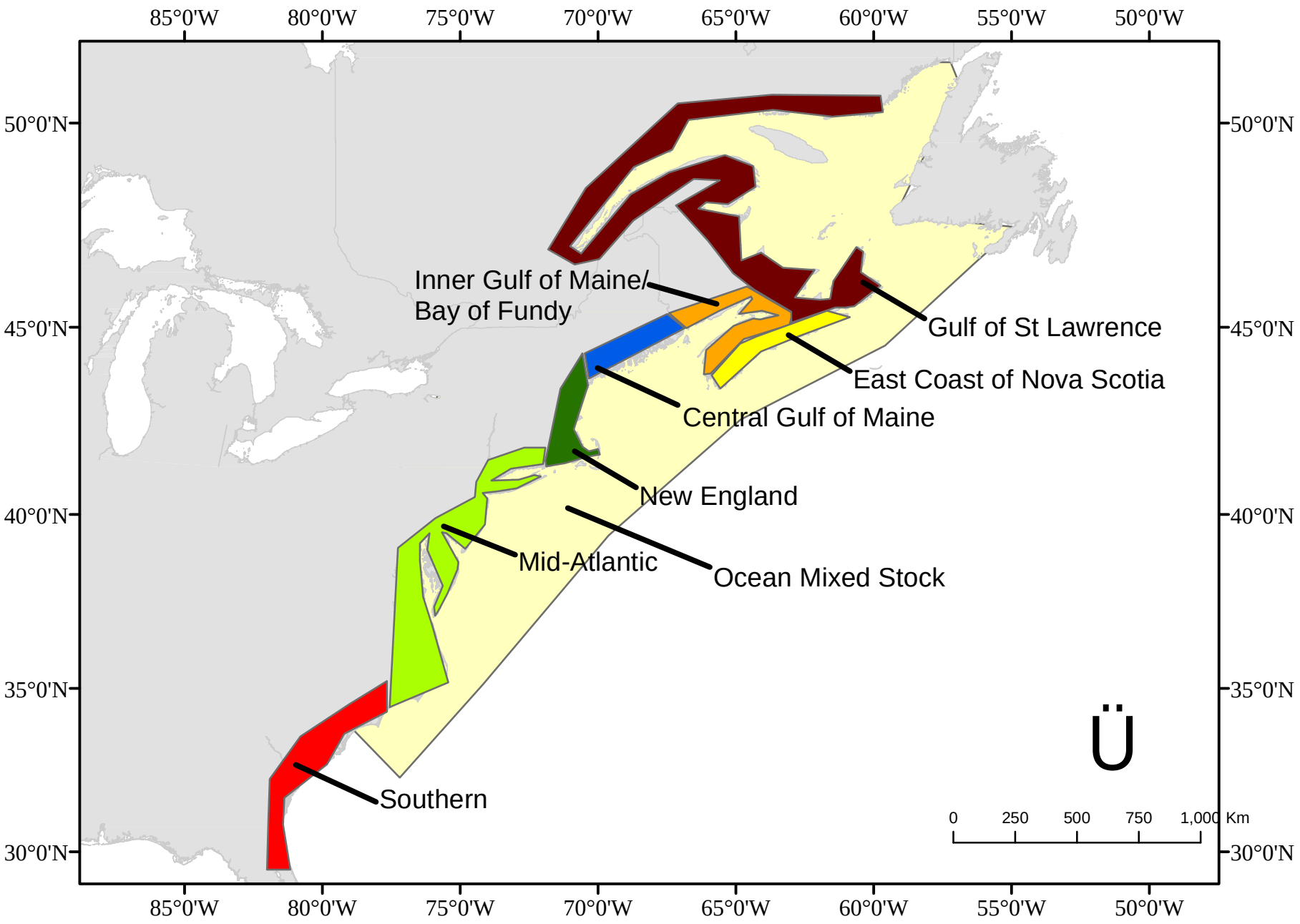
Neves, R. J. (1981). Offshore distribution of alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*, along the atlantic coast. Fishery Bulletin 79(3): 473-485.

Rulifson, R.A., McKenna, S.A. and M.L. Gallagher. 1987. Tagging studies of striped bass and river herring in upperBay of Fundy, Nova Scotia. N.C. Dep. Nat. Resour. Comm. Develop., Div. Mar. Fish., Completion Rep. AFC-28-1, E. Carolina Univ., Greenville, 175 p.

Stone, H. H. and B. M. Jessop (1992). Seasonal distribution of river herring *Alosa pseudoharengus* and *A. aestivalis* off the Atlantic coast of Nova Scotia. Fishery Bulletin 90(2): 376-389.

Jordaan - Proposed alewife *Alosa pseudoharengus* stock structure




Jordaan - Proposed blueback herring Alosa aestivalis stock structure
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Bay of Fundy
Gulf of St Lawrence
East Coast of Nova Scotia
Central Gulf of Maine
New England
Mid-Atlantic
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River Herring (Alewife and Blueback) Stock Structure Opinion

Kevin Sullivan
NH Fish and Game Department
June 28, 2012

After participating in the Stock Structure Workshop, held June 20-22, 2012 at the NMFS Northeast Regional Office, Gloucester, MA and reviewing and considering all data presented and provided thereafter I would like to provide my opinion and explanation on the stock structure of river herring (alewife and blueback) along the Atlantic Coast of the United States.

Stock Structure Opinion:

Alewife: 4 U.S. + 1 Canadian w/ Single At-Sea Mixing Stock (Fig 1)
Blueback Herring: 4 U.S. + 1 Canadian w/Single At-Sea Mixing Stock (Fig 2)

Explanation:

The New Hampshire Fish and Game Department has conducted monitoring of the annual spawning runs of river herring on the coastal rivers (Lamprey R., Oyster R., Cocheco R., Exeter R., Taylor R., Winnicut R.) of New Hampshire since 1978. The relatively small spatial scale of the river systems in New Hampshire along with the independent fluctuations in annual spawning run sizes and historical species composition of each run lends support to the classification of each river system as an individual stock. Similar evidence presented by Mr. Armstrong, identifying significant difference in mean length of alewife between rivers within the state of Massachusetts would also support stock identification at the river level. This difference has not been observed on the six coastal rivers within New Hampshire, but the fact that five of the six rivers are in the Great Bay Estuary may indicate that these differences are only occurring for river herring across separate drainages, not necessarily between rivers within close proximity. Little evidence has been provided to date to confirm the exact level of specificity/fidelity that river herring exhibit in returning to their exact natal streams, and to quantify the level of straying between neighboring streams and possibly between large drainages. The strongest support of spawning site fidelity is that conducted by Jessop in 1994 through tagging in the St. John River, NB where tagged fish returned subsequent years. Additional research discussed at the workshop was that of Gahagan 2012, Evaluation of Otolith Microchemistry for Identifying Natal Origin of Anadromous River Herring in Connecticut. However, this study was unable to provide substantial support to river-specific homing due to similarities in water chemistry among rivers within close proximity, but does suggest that the technique can be useful for distinguishing between individuals from chemically distinct systems.

A rapid decline of river herring abundance has occurred in two river systems (Oyster River and Taylor River) of New Hampshire where spawning runs were historically dominated by blueback, while abundance of river herring in predominantly alewife runs have varied inter-annually but have oscillated around a mean value in recent years. The species composition of rivers within New Hampshire has shifted towards single species dominance (alewife) and rivers of previous blueback dominance have exhibited a higher proportion of alewife due to large reduction in abundance of blueback in those rivers. This suggests that the two species are likely experiencing separate exploitation, natural

mortality, or predation levels at sea (outside of spawning rivers) due to a stock structure division or at least a divergence in seasonal movements, annual migratory or behavioral patterns. For these reasons and the personal communications of other individuals at the workshop indicating that it appears that the magnitude of decline in populations of blueback has been much greater than that of alewife herring, **the stock structure should be distinct at the species level, with separate stocks defined for alewife and blueback herring**.

The most compelling information presented to identify division of stocks of each species along the Atlantic coast from Maine to Florida was that presented by Mr. Gephard of work conducted in collaboration with Palkovacs. The genetic distinction of populations of alewife and blueback herring returning to streams to spawn was shown to provide the presence of five distinguishable stock of alewife and four distinguishable stocks for blueback herring. The proposed stock structure based on genetic results are remarkably similar to geographic divisions along the coast, which have been used to classify other fish stocks as well as delineate distributions of species. These divisions would be, North Atlantic/Gulf of Maine (north of Cape Cod), Mid-Atlantic (south of Cape Cod to Cape Hatteras), and South Atlantic (south of Cape Hatteras to southern Florida). The genetic data provides further resolution for both species; however I am in disagreement with the likelihood of some delineation, specifically the lack of distinction in alewife and blueback stock structure of river herring from north and south of Cape Cod as well as the singular alewife stock of the Connecticut River. Further sampling needs to be completed and inclusion of more river systems, and my opinion is that the Connecticut River proposed stock based on genetic markers may be included with the alewife stock from Rhode Island and Massachusetts, south of the Cape or may mirror the stock structure presented for bluebacks within the same study where fish sampled from the Connecticut River and Hudson River were proposed to be included in the Mid-Atlantic Stock. Genetic data presented by Mr. Willis is in partial agreement with the distinction between river herring north of Cape Cod and those south of Cape Cod with the inclusion of the Nemasket River in Massachusetts, but also would support a division of river herring stocks between major river drainage systems, with presence of sub-populations within Maine**. Therefore, my opinion of stock structure would include the following (shown in Figure 1) for alewife: Northern New England, Southern New England, Mid-Atlantic, and North Carolina Stocks; and the following (shown in Figure 2) for blueback herring: Northern New England, Southern New England, Mid-Atlantic, and Southern Stocks. Additionally, based on river-specificity of individual fish for consecutive spawning runs (with some straying) I feel that as a part of this stock structure it should be considered that each individual river or at the least each individual major river drainage should be deemed a sub-stock/population within each.**

However, there is a considerable deficit of directed research as well as non-directed ancillary data sources to determine the stock structure of either species while 'at-sea'. Mr. Cieri and Mr. Jordaan presented separately data from the Maine/New Hampshire Inshore Trawl Survey, NMFS Bottom Trawl Survey, and the Northeast Observer Program which did provide some information on the location of river herring while at

sea. Both species of river herring are caught as bycatch in the Atlantic herring fishery, and both are caught in research bottom trawl surveys throughout the surveyed areas, with a suggestion of assemblages nearer to mouths of large river drainages. This data is uninformative to the origin of the herring encountered in these surveys and is unable to provide insight into which of the stocks or geographic regions are represented in the at sea sampling. There is a large potential to use the genetic 'fingerprints' of alewife and blueback stocks established through the work of Palkovacs, Willis, and Gephard to attempt to classify the at-sea sampling of herring catches to their natal or distinct stock locations, but that work has not been completed at this time. Additionally, unpublished data which was discussed at the workshop by Rulifson for a tagging program of approximately 19,000 river herring at sea in Canadian waters did indicate that tag return rates were very low, but that the reported alewife returns were all caught around the Bay of Fundy, but blueback tag returns were from as far away as North Carolina and Massachusetts. A study conducted by Neves 1963-1978 also indicates that both species occur throughout various locations when at sea, and there is a possible seasonal migration of a large grouping of river herring from the northern regions (Gulf of Maine, Georges Bank) in the summer and early fall, but large scale movements south to mid-Atlantic for late fall and winter. **Therefore, in my opinion the stock structure of alewife and blueback herring should include (or be taken into strong consideration when defining) a seasonal designation to account for the fact that all genetic, abundance, species, and morphometric information used to establish potential stock structure originates from sampling occurring during the spawning runs in spawning rivers/major river drainages and although little evidence is available at this time to accurately describe the at sea stocks, that which does exist suggests that there is large coastal migration and mixing of alewife and blueback while at sea for the majority of the year and during overwintering periods.**

Figure 1:
Alewife stock structure opinion (K. Sullivan): 4 U.S. Stock Complexes with a single at-sea mixing zone, plus 1 Canadian stock.

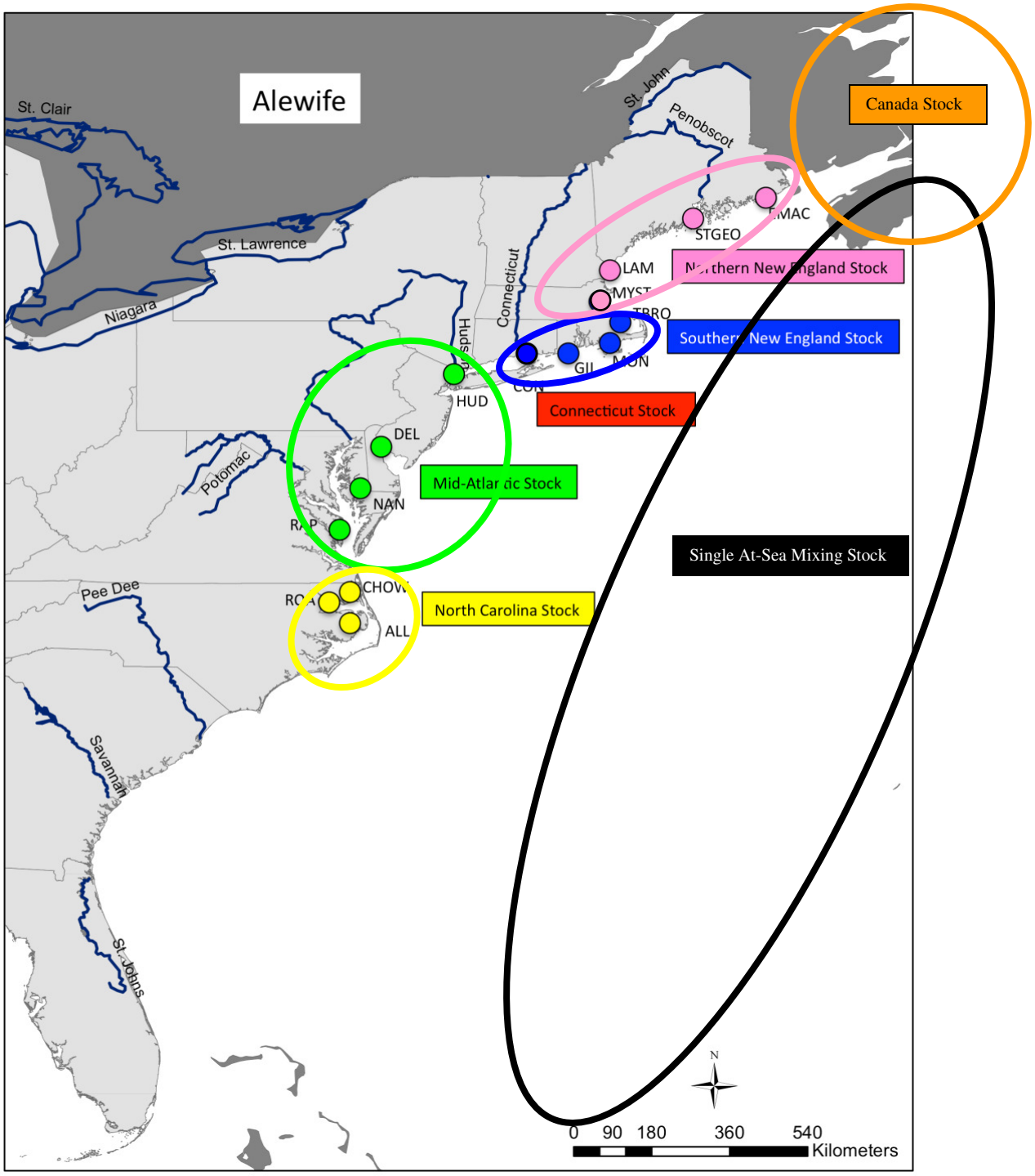
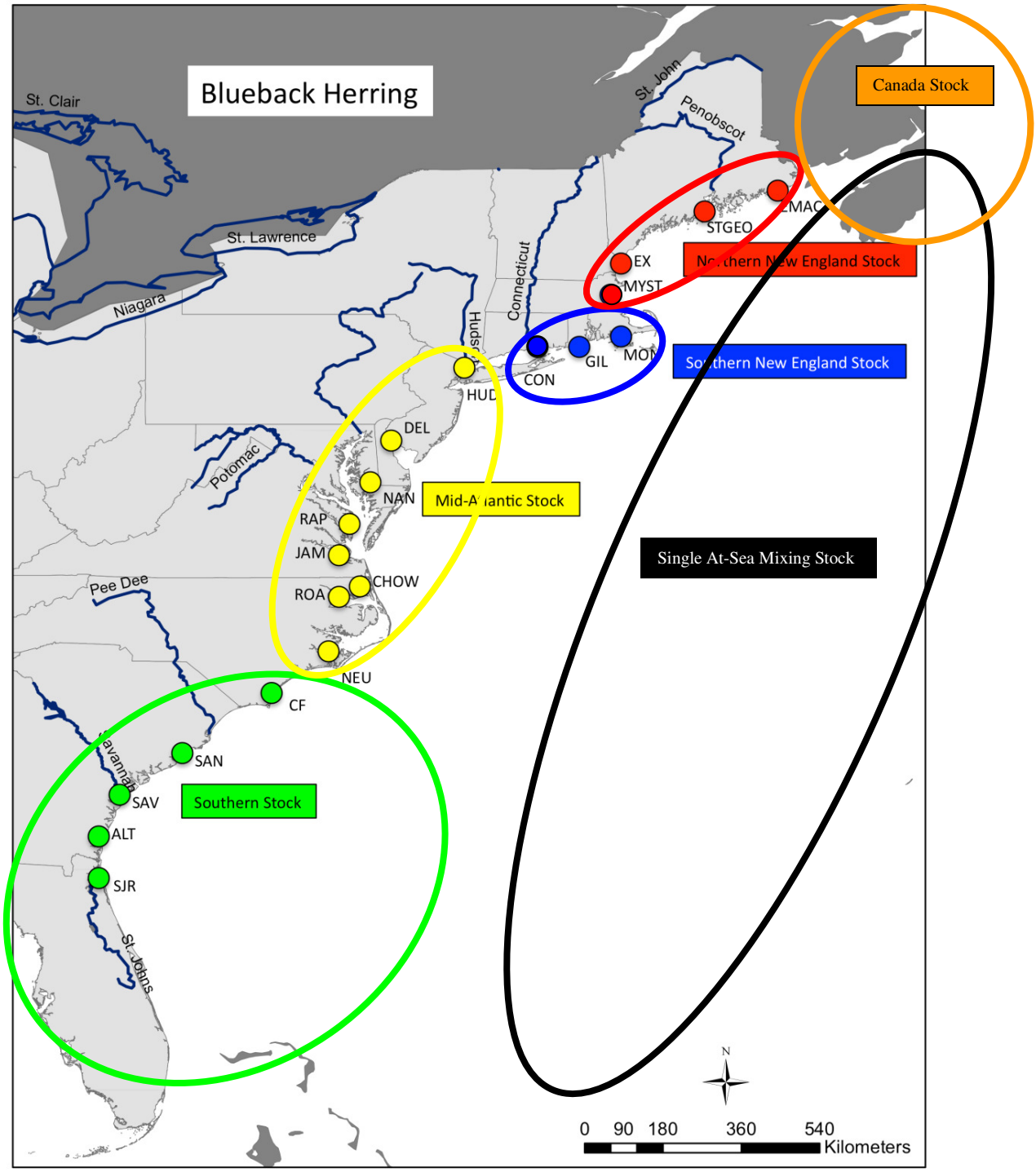


Figure 2:
Blueback herring stock structure opinion (K. Sullivan): 4 U.S. Stock Complexes with a single at-sea mixing zone, plus 1 Canadian stock.

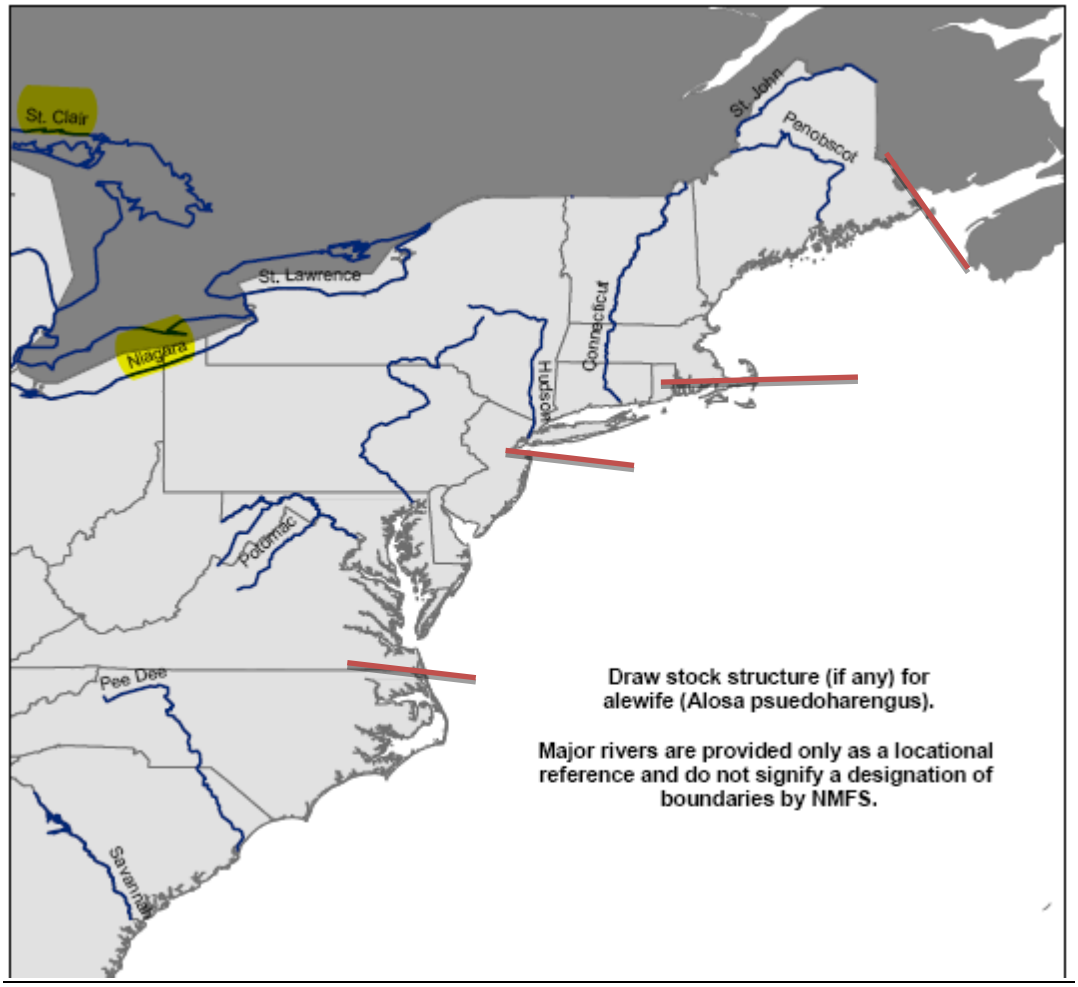


Stock Structure Workshop Expert Opinion- Theo Willis (University of Southern Maine, Alewife Harvesters of Maine)

Alewife Stock Structure Recommendations –

For alewife I would propose (1) a New England stock that goes from the Maine border south to the interior of Cape Cod Bay; (2) a Long Island Sound stock that goes from exterior Cape Cod Bay to Raritan Bay; (3) a mid-Atlantic stock that goes from Raritan Bay to the North Carolina border; (4) a North Carolina stock.

1. The northern New England stock is based on the Willis-Bentzen genetics work for Maine and Atlantic Canada, showing a divergence in populations at the Maine border and little differentiation within Maine, and the Palkovacs-Gephard genetics work, showing a Southern New Engalnd and Northern New England group. The stock I propose here does not match up perfectly with the Palkovacs-Gephard results. The deviation takes into account observed patterns in abundance that separate Maine and NH alewife trends from the South shore of Massachusetts. Also, historic records of population trends demonstrates that heavy fishing south of Cape Cod had a more visible effect on the Long Island Sound river herring runs than the runs north of Cape Cod (B. Leavenworth, UNH, personal communication). A model developed by MA DMF predicts, with considerable accuracy, that local rainfall conditions had a significant effect on alewife declines in the North Shore region.
2. This stock is of considerable concern to the petitioners and managers and has shown the most dramatic declines in recent years. Historic data also points to the runs in this area as being particularly vulnerable to fishing pressure and predation pressure. This area also comprises a number of small coastal streams and ponds with small runs where Palkovacs et al. 2008 indicated there might be a high degree of straying.
3. Agrees with the Palkovacs – Gephard genetics results.
4. Agrees with the Palkovacs – Gephard genetics results.



Blueback herring Stock Structure Recommendations

The information available for blueback herring points to fewer potential stocks and a species that may have longer migration routes than alewife. I would propose (1) a New England stock that goes from the Maine border south to the interior of Cape Cod Bay; (2) a Long Island Sound stock that goes from exterior Cape Cod Bay to Raritan Bay; (3) a mid-Atlantic stock that goes from Raritan Bay to Moorehead City North Carolina; (4) a southern stock that goes from Moorehead City through Florida.

1. The New England stock is based on the Palkovacs- Gephard genetics work, but with the same assumptions listed for alewife above. Differentiation between the two species has been so poor for so long that it must be considered reasonable to assume that observations for alewife apply to blueback herring. Given that, it makes sense to combine the Northern and Southern New England groups based on past fishing activity. There is not enough data from Maine to determine whether declines seen in MA and NH extend into Maine.

2. This stock is of considerable concern to the petitioners and managers and has shown the most dramatic declines in recent years. Historic data also points to the runs in this area as being particularly vulnerable to fishing pressure and predation pressure.
3. Agrees with the Palkovacs – Gephard genetics results.
4. Agrees with the Palkovacs – Gephard genetics results.