Shad and River Herring Technical Committee Report: Recommendations for Evaluating Bycatch Removals in Directed Mixed-stock Fisheries in State Waters

October 2021

1 INTRODUCTION

The American Shad 2020 Benchmark Stock Assessment and Peer Review Report was accepted for management use in August 2020. The assessment found that American shad remain depleted on a coastwide basis, likely due to multiple factors, such as fishing mortality, inadequate fish passage at dams, predation, pollution, habitat degradation, and climate change. One of the priority research recommendations identified in the stock assessment and highlighted by the Technical Committee (TC) was to "conduct annual stock composition sampling through existing and new observer programs from all mixed-stock fisheries (bycatch and directed). Potential methods include tagging (conventional external tags or acoustic tags) of discarded catch and genetic sampling of retained and discarded catch. Mortality rates of juvenile fish in all systems remain unknown and improvement in advice from future stock assessments is not possible without this monitoring. Known fisheries include the Delaware Bay mixed-stock fishery and all fisheries operating in the Atlantic Ocean (U.S. and Canada) that encounter American shad (see Section 4.1.4 in the stock assessment report)."

To address this recommendation, the TC recommended that the Board task them to consider methods that could be used to understand and reduce impacts of mixed-stock catch on stocks outside the area where directed catch occurs. Therefore, at the February 2021 meeting the Board tasked the TC with "developing methods to evaluate bycatch removals in directed mixed-stock fisheries in state waters in order to understand and reduce impacts to stocks outside the area where directed catch occurs." The TC formed a task group to focus on this work. The task group produced the following report, and recommendations were developed by the full TC.

2 IDENTIFICATION OF MIXED-STOCK SHAD FISHERIES AND AVAILABLE DATA

After initial discussions, the task group requested that the full TC submit any data that could be used to identify where mixed stock shad fisheries may be taking place in state waters as well as data that might be useful in evaluating the impacts of these mixed stock fisheries on the individual stocks being harvested. The task group received a number of fishery dependent and independent data sets including data from tagging studies, by-catch genetic analysis, commercial landings, and long-term general abundance surveys (Table 1). The tagging studies and genetic analysis provided proved useful for identifying mixed stock shad fisheries within the Delaware Bay and Winyah Bay. Given the quantity of relevant data available from the Delaware Bay, this system was used as a test case for developing methods to evaluate the potential impacts of mixed stock harvest on individual stocks which could be applied to the other mixed stock fisheries that were identified.

The table below details the data sets submitted to the task group and used to identify or rule out potential mixed stock fisheries along the coast. From these submitted data, the task group

was ultimately able to identify mixed stock fisheries in the Delaware Bay and Winyah Bay systems. These data were used to explore the potential effects of mixed stock fisheries on out of basin stocks and identify management strategies that may be useful for limiting these potential effects.

Table 1. Available Data Pertaining to Mixed-stock Shad Catch on the Atlantic Coast

Data Set	***System***	***Time Series***
New Jersey Adult Shad Tagging Survey	Delaware Bay	1995-2019
New Jersey Commercial Landings Reports	Delaware Bay	1980-2019
Delaware Commercial Landings Reports	Delaware Bay	1980-2019
Waldmen et al., Genetic Study, 2014	Delaware Bay	2009-2010
Bartron & Prasko, Genetic Study, 2021	Delaware Bay	2017-2019
Hudson River Adult Haul Seine Index	Hudson River	1988-2017
North Carolina, Acoustic Tagging Study	Albemarle Sound	2017-2018
South Carolina Adult Tagging Survey	Winyah Bay	2003-2005, 2010-2020
Maryland Adult Shad Tagging Survey	Susquehanna River	1987-2019

2.1 **Mixed-stock bycatch in state waters**

2.1.1 Delaware Bay

The shad fishery within the Delaware Bay is generally considered the most significant source of mixed stock harvest within states' waters. Commercial fisheries in the bay and upper estuary are carried out by fisherman from the states of New Jersey and Delaware. The New Jersey fishery is a directed gill net fishery, typically harvesting between 10,000 to 20,000 pounds of shad per year. The shad harvested in Delaware are typically caught as bycatch in the directed striped bass gill net fishery. Landings from Delaware fluctuate significantly, averaging around 16,000 pounds per year over the past decade, with larger yearly shad catches being seen when the fishermen switch to smaller mesh sizes when targeting smaller striped bass.

A variety of studies have been completed using both tag recapture data and DNA analysis to determine stock origin of American shad within the Delaware Bay. New Jersey's Bureau of Marine Fisheries has been tagging shad in the lower bay continually since 1995 with recapture data showing about 40% of American shad recaptures occurring within the Delaware Basin. The remaining 60% being reported from the ocean and within river systems spanning from the St. Lawrence River in the north and as far south at the Santee River in South Carolina with the Hudson River making up the largest proportion (17.5% - 34.4%) of out of basin recaptures. DNA analysis by Waldmen et al., 2014, found varying proportions of stock representation from the commercial harvest depending on the analysis method used with Delaware Basin fish representing between 24% and 53% of the harvest and Hudson River fish making up the largest proportion of out of basin harvest. A more recent study by M. Bartron and L. Prasko with the USFWS Northeast Fishery Center using similar methods to Waldmen et al., 2014, found similar varying proportions of Delaware Basin versus out of basin stock compositions. The Hudson River stock represented the largest proportion of out of basin fish in this study as well. As a result of these high proportions of out of basin American shad that are caught in the

commercial fisheries in Delaware Bay, a Mixed Stock Fishery Benchmark has been implemented as part of the Sustainable Fishery Plan to minimize the impact of the Delaware Bay fishery on out of basin stocks.

2.1.2 Winyah Bay System, SC

The Winyah Bay System is made up of five main rivers and encompasses parts of North Carolina and South Carolina. Historically, American shad inhabited all of the Great Pee Dee River 280 kilometers (km) and had access to all main stem tributaries throughout the 22,258 km^2 watershed within South Carolina, including Little Pee Dee River (187 km), Lynches River (225 km), Black River (243 km), and Waccamaw River (225 km) in both South Carolina and North Carolina. The South Carolina commercial shad fishery is a directed gill net fishery, with the bulk of the catch occurring in the lower Pee Dee and Waccamaw Rivers. Landings fluctuate due to river discharge, but average around 24,000 – 35,000 pounds per year.

Since 2010, fishery-independent monitoring occurs annually in the lower Waccamaw River, prior sampling occurred on a rotational basis and included years 2003-2005. Sampling consists of using drift gill nets along a stretch of river in the Intra-coastal Waterway (ICW) where all captured shad are tagged with dart tags and released to estimate fishing mortality rates in this system. Tag return rates varied based on fishers' participation and with recent changes to regulations to demonstrate sustainability, have decreased significantly. Return rates during early years in the time series indicated a straying rate of ~25% (those returns from other rivers within the System). However, the majority of these occurred in the Great Pee River, a major high flow tributary river connected to the Waccamaw River and known spawning area for American shad. Therefore, tagging information alone cannot be used to distinguish stock composition.

Beginning in 2020 and continuing annually, fin clips were taken from captured shad in the lower portions of the Waccamaw and Great Pee Dee Rivers to better understand genetic mix stock composition of returning shad in the Winyah Bay System. In a similar effort as described above for Delaware Bay, results of genetic analysis for these samples should provide some missing information regarding number of stocks and composition of those stocks. If warranted, this information can then be used to update Sustainable Fishery Management Plans for the Winyah Bay System.

3 METHODS FOR EVALUATING BYCATCH REMOVALS IN DIRECTED MIXED-STOCK FISHERIES

The task group chose to take a tiered approach evaluating available data and potential methods for addressing this task, with the Delaware Bay mixed stock fishery serving as an example. Three tiers were developed based on (1) methods applicable with the quantity and quality of data currently available (first-tier), (2) methods applicable with data that could reasonably be collected without significant changes in near term data collection efforts (second-tier), and (3) advanced methods that would provide the most robust information but also would require significant changes in data collection efforts (third-tier). This tiered approach was used in order to allow the Board to consider several management approaches for addressing the effects of

mixed stock fisheries while also considering the availability of information and associated timelines for each tier.

3.1 First-Tier Methods

The first-tier represents the evaluation method that can currently be undertaken given the quantity and quality of fishery dependent and independent data available from existing data collection efforts.

Relative F with static stock composition

Age data and mortality estimates for American shad have been collected and calculated relatively inconsistently in regards to the stocks associated with the mixed stock fisheries. As a result, modeling efforts using these data as applied to evaluating impacts of mixed stock fisheries on out of basin stocks have not yielded useful results.

Data that have been consistently collected over appreciable time series include commercial landings reports and fishery independent relative abundance indices which can be used to develop a relative fishing mortality (*F*). When evaluated in conjunction with stock composition data (e.g., tag recapture data, genetic data), it is possible to generate stock specific relative *F*s for American shad harvested in mixed stock fisheries.

The task group determined all required data are currently available to evaluate the impact of the commercial American shad fishery in the lower Delaware Bay on Hudson River stock American shad using this relative *F* method. Hudson River stock shad represent the largest proportion of out basin shad harvested in this fishery. For this method, the proportion of Hudson River shad in the Delaware Bay mixed stock fishery, (24.5% derived from tag recapture data), can be applied to the yearly total mixed stock landings to derive an estimate of Hudson River stock removals (average of 4,443 lbs per year, 2003-2019). The yearly Hudson River stock removals can then be divided by the yearly index value generated from the New York Hudson River Adult Shad Haul Seine Survey to generate a yearly and time series average relative *F*.

Hudson River stock proportions have also been generated for the Delaware Bay using genetic analysis in several studies with varying proportions that could be used to generate alternative total Hudson River stock removals and subsequent relative *F* estimates. The caveat to using the proportions of Hudson River stock generated with the genetic analyses is that these represent proportions based on 1 to 4 year snapshots versus the tagging data which yields an average proportion over the entire time series being analyzed. The relative *F* method explored here for the Delaware Bay mixed stock fishery could readily be applied to other known mixed stock fisheries where the appropriate data (commercial landings, FI relative abundance index, and stock proportions) are available.

Management Approaches

Options to address the impacts of mixed stock harvest on out of basin stocks, as evaluated using stock specific relative *F*s, include establishing a relative *F* benchmark and associated management triggers based on a time series when rates of harvest were deemed acceptable.

Alternatively, catch caps can be developed to keep the harvest of out of basin stocks of American shad to an acceptable level and/or area restrictions can be implemented to reduce or eliminate fishing effort within areas where mixed stock fisheries are known to occur.

Timing of Analysis

Data are available to support this analysis in the Delaware Bay mixed stock fishery immediately. These data are not immediately available for a similar analysis in the Winyah Bay system.

3.2 **Second-Tier Methods**

The second-tier includes a method that offers improvements to the first-tier method with minor changes to existing data collection efforts.

Relative F with time-varying stock composition

The relative *F* method with static stock composition assumptions informed by existing snapshot sampling described in the first-tier could be improved with increased frequency of stock composition monitoring. Uncertainty in estimates would decrease with increased frequency of sampling (e.g., annual sampling) due to interannual variation in stock composition driven by factors like spatial and temporal variation of fishing and abundance changes of stocks encountered.

Three high priority research recommendations focused on collection of stock composition data (storage infrastructure, population baseline data, and mixed stock data) were included in the 2020 stock assessment and would address current limited and opportunistic sampling that would support the first-tier method. These recommendations led to the development of an alosine genetic sample repository at the Leetown Research Laboratory of the United States Geological Survey Eastern Ecological Science Center (USGS EESC). This effort aims to collect tissues from spawning rivers to create population baselines. Probabilistic genetic analysis would be used to assign individuals from the mixed stock fisheries to their respective populations. Hence, it will be possible to partition bycatch into its component stocks and identify populations that are potentially more affected. Researchers at the USGS EESC are working in collaboration with researchers at Cornell University to develop a panel of single nucleotide polymorphisms (SNPs) for higher resolution stock assignment. The principal advantage of these markers over microsatellites is their repeatability and accuracy. The repository addresses infrastructure needs, improved population baseline data, and mixed stock data from fisheries occurring in federal oceanic mixed stock fisheries, but additional support is necessary to sample mixed stock fisheries in state waters including the Delaware Bay mixed stock fishery.

Management Approaches

Management approaches would be the same as for the first-tier method, but would informed by estimates with greater certainty.

Timing of Analysis

This method could be applicable after as little as one year of stock composition data sampling and analysis in the Delaware Bay fishery. Updated estimates could then be provided each year

new stock composition data are collected. These data are not immediately available for a similar analysis in the Winyah Bay system.

3.3 **Third-Tier Methods**

Catch Impact Analysis

A catch impact analysis would use an adult equivalents model as described by Ianelli and Stram (2015). This analysis divides mixed stock fishery removals of potential spawners, both from the current fishing year and previous fishing years (i.e., removals of immature or repeat spawning fish from previous years), by the sum of bycatch removals and spawning escapement. This impact estimate ranges from zero to one, with zero indicating no impact from the fishery, one indicating complete removal of an annual spawning run by the fishery, and an increasing impact as the estimate increases from zero to one. A feature of these estimates that offers an improvement to the first- and second-tier methods is that they can be interpreted as absolute exploitation estimates as opposed to relative exploitation estimates. Absolute exploitation estimates can more readily be compared to biological reference points.

This method would quantify any mixed stock fishery impacts and, if generated in a time series, provide trends of these impacts through time. However, the method does not provide reference point estimates, requiring the need for ad hoc reference points developed through additional simulation analyses or other methods (e.g., per-recruit analyses) if used for management.

This method may be the better suited of the third-tier methods for stocks that are under moratorium or have very limited in-river removals, as removal data from established and directed fisheries improve utility of traditional stock assessment models like statistical catch-at-age models.

Data Requirements

Total Mixed Stock Fishery Removals

Total removals of shad by the mixed stock fishery are necessary, including both fish retained for harvest and fish discarded that die due to interaction with the fishery. Total discards, both discarded dead and released alive, and a discard mortality rate are needed to estimate total dead discards.

- Delaware Bay Mixed Stock Fishery: Total harvest data are reported for the Delaware Bay mixed stock fishery. Complete harvest data are available back to 2002 and incomplete data (NJ harvest only) are available back to 1985. Delaware harvest data prior to 2002 were reported without spatial information and would require assumptions to delineate into mixed stock harvest (lower bay) and harvest of the Delaware River stock only (upper bay). However, data limitations (see below) would preclude applying this method retrospectively to these earlier years. Anecdotal information indicates that discards of American shad in this fishery are negligible.

Biological sampling of mixed stock catch is necessary to determine the number of spawners that would have been repeat spawners had they not been removed by the fishery. This would require length, age, and repeat spawn mark sampling. If the mixed stock fishery encounters immature shad, maturity ogives would also be necessary.

- Delaware Bay Mixed Stock Fishery: Biological sampling data are not regularly collected from the Delaware Bay mixed stock fishery. It can be assumed the fishery is only encountering mature shad returning to spawn, precluding the need for maturity ogives. There were several research recommendations in the 2020 stock assessment to further evaluate error in spawn mark determinations which would help understand utility of these data for this type analysis.

Stock composition monitoring in the mixed stock fishery would also be required. Snapshot sampling (i.e., sampling less frequently than annual intervals) could be used. However, as with the relative *F* method, uncertainty in estimates would likely decrease with increased frequency of sampling due to interannual variation in stock composition driven by factors like spatial and temporal variation of fishing and abundance changes of stocks encountered.

- Delaware Bay Mixed Stock Fishery: There are stock composition estimates available for 2009-2010 (Waldman et al. 2014). There are additional, recent stock composition estimates from 2017-2020 (Bartron and Prasko 2021), but additional estimates (i.e., stock composition estimates across baseline groups for the lower Delaware Bay sampling region only) would be necessary to support a catch impact analysis. The USGS EESC alosine repository does provide a pathway for improved stock composition data, but, again, additional support is necessary to sample the Delaware Bay mixed stock fishery.

A study (or assumptions) is needed to determine migration patterns of the stocks impacted relative to the timing of the mixed stock fishery and spawning. If the mixed stock fishery occurs following the spawning run for a given stock, the fishery impacts the stock the following year and beyond (i.e., removal of potential repeat spawners). If the mixed stock fishery occurs prior to the spawning run, the fishery impacts the stock in the same year and beyond.

- Delaware Bay Mixed Stock Fishery: Based on the timing of this fishery and concurrent sampling by a fishery-independent survey that encounters unripe fish, it can be assumed that all fishing occurs pre-spawn.

Spawning Escapement Counts

The analysis requires escapement count data (absolute abundance of fish as they return to their spawning grounds). Escapement counts could be observed counts at a choke point (e.g., fishway count) or extrapolations of relative abundance measured by a fishery-independent survey.

- Delaware Bay Mixed Stock Fishery: There are fishway counts for three stocks that account for at least 1% of the Delaware Bay mixed stock fishery, according to 2010 stock composition estimates (Waldman et al. 2014), that were considered reflective of

interannual abundance changes during the 2020 stock assessment: the Essex Dam fishway count on the Merrimack River, the Holyoke Dam fishway count on the Connecticut River, and the Boshers Dam fishway count on the James River. Unfortunately, these are considered indicators of relative abundance, not absolute spawning escapement, because of their locations above some American shad spawning grounds and river flow impacts to fishway operation throughout the spawning season.

Marine Survival

Estimates of marine survival-at-age are needed to correctly account for removals of potential repeat spawners. Marine survival data are used to decrement removals of potential spawners in previous years that would have experienced mortality from other causes. Assumptions could be made in the analysis, but any information on marine survival and how it changes through time would reduce uncertainty of estimates.

- Delaware Bay Mixed Stock Fishery: These estimates remain a primary limitation in assessment of all American shad stocks. The 2020 stock assessment provides estimates of baseline natural mortality based on the life history of the species that could be used for this component of total mortality. Fishing mortality due ocean bycatch has not been quantified. Ocean bycatch has been declining in recent years and assumptions about this mortality may become less impactful if this declining trend continues, but current contribution to total mortality is unknown.

Statistical Catch-at-Age Model

Statistical catch-at-age models could be used to estimate fishing mortality and exploitation rates of fisheries that remove portions of the stock abundance, including mixed stock fisheries. Statistical catch-at-age models are forward-projecting, age-structured models that track total stock abundance and exploitation rates through time according to data collected on changes in abundance-at-age and fishery removals-at-age. Fishing mortality and exploitation rates could be compared to those of other fisheries (e.g., in-river, stock-specific fisheries) and reference points to determine bycatch fishery impacts. To estimate mixed stock catch impacts, these models would be applied to individual stocks. For example, a model would need to be applied to Hudson River stock data sets, including mixed stock fishery removals of Hudson-origin fish, to estimate mixed stock catch impacts to the Hudson River stock. Therefore, the stock of interest would need all data sets required for these models. These models were applied to two stocks in the 2020 stock assessment that were negligible components of the Delaware Bay mixed stock fishery, according to Waldman et al. (2014), but data limitations precluded application to other stocks. Reference points would likely need to be estimated with coupled per-recruit analyses. This method would be less applicable to stocks under moratorium, which are likely to remain in data limited situations and be at low abundances that are encountered with high variability by mixed stock fisheries.

Data Needs

These models would require similar data sets as the catch impact analysis, with a few exceptions discussed below.

Relative Abundance

Total escapement counts required for the catch impact analysis are not required for statistical catch-at-age model, as these are estimated with these models using relative abundance data.

- Delaware Bay Mixed Stock Fishery: Relative abundance data are available for many of the stocks occurring in the Delaware Bay mixed stock fishery (see tables 13-20 in the 2020 stock assessment).

Total Fishery Removals

This method also requires total removals along with age composition data from biological sampling for all fisheries, whereas the catch impact analysis is still applicable if data from some removal sources (e.g., ocean bycatch) are unavailable.

- Delaware Bay Mixed Stock Fishery: As noted for the catch impact analysis, stock-specific ocean bycatch removals remain a major data limitation in assessment of American shad stocks. Recreational fishery removals are also a data limitation in some stocks impacted by the Delaware Bay mixed stock fishery inducing the Delaware River stock and Connecticut River stock.

Management Approaches

These methods could provide mixed stock catch impacts relative to established reference points, which could be used to trigger management responses (e.g., effort controls, catch reductions). However, this would not be real-time information and would only inform reactive management responses in subsequent fishing seasons.

Timing of Analyses

The catch impact analysis would be most applicable after at least a time series of data equal to the age structure in the population impacted by the fishery. This would be approximately nine and six years for mixed stock fisheries that remove all age classes and just mature age classes, respectively. Statistical catch-at-age models would require longer time series of data than the catch impact analysis that are dependent on contrast in the population over the time series. This analysis focused on the Delaware Bay mixed stock fishery, but the data requirements, timing of analyses, and management approaches would apply to the Winyah Bay system as well.

4 TECHNICAL COMMITTEE RECOMMENDATIONS

4.1 Recommended Path Forward

The TC reviewed the methods considered by the task group for evaluating bycatch removals in directed mixed-stock fisheries in state waters in order to understand and reduce impacts to stocks outside the area where directed catch occurs. Each tier was assessed based on the current data available and the required change in data collection efforts that would be necessary to successfully conduct each given method of analysis. The pros and cons of each tier were weighed with special attention being paid to increases in data sampling and analysis required to complete more robust analysis methods. The TC chose to prioritize considered

methods based upon robustness of analysis used while also considering whether data requirements for each method could be practically achieved.

4.2 **Management Recommendations**

After considering all of the options available, the TC recommends the second-tier method be used for evaluating bycatch removals in directed mixed-stock fisheries. Based on these methods, the TC recommends management strategies also be developed to reduce impacts of out of basin harvest in these fisheries. This tier involves developing a Relative F index based on increased genetic sampling and/or tagging efforts which could potentially provide annual stock composition of mixed stock landings. This method is preferable to the current first-tier methods of applying a historical average to stock assignment based on past tagging and DNA studies as regular DNA analysis can account for yearly fluctuations in stock composition of the harvest. While the TC acknowledges that the third tier methods would provide the most robust analysis of mixed stock fishery impacts, the required increase in data collection and sampling efforts could not practically be completed by agencies involved in mixed stock fisheries without a significant increase in staff time and resources. The TC feels that the minor increase in sampling and analysis required under the recommended second-tier methods could easily be achieved and could provide a meaningful increase in assessment quality over the status quo (first-tier) methods.

Whether the Board agrees with the TC recommendation or prefers an alternative approach, the preferred method should be incorporated into the appropriate Sustainable Fishery Management Plans through the development of management strategies, benchmarks, and triggers for addressing the impacts of mixed-stock catch. The Delaware River Basin Fish and Wildlife Management Cooperative is currently in the process of updating the American Shad Sustainable Fishery Management Plan for 2022; if desired, this update could potentially include a new mixed-stock benchmark based on the methods evaluated by the TC and recommended by the Board.

References

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