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ARTICLE

Phenological Variation in Spring Migration Timing of Adult Alewife in Coastal Massachusetts

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Abstract

The timing of biological events in plants and animals, such as migration and reproduction, is shifting due to climate change. Anadromous fishes are particularly susceptible to these shifts as they are subject to strong seasonal cycles when transitioning between marine and freshwater habitats to spawn. We used linear models to determine the extent of phenological shifts in adult Alewife Alosa pseudoharengusas they migrated from ocean to freshwater environments during spring to spawn at 12 sites along the northeastern USA. We also evaluated broad scale oceanic and atmospheric drivers that trigger their movements from offshore to inland habitats, including sea surface temperature, North Atlantic Oscillation index, and Gulf Stream index. Run timing metrics of initiation, median (an indicator of peak run timing), end, and duration were found to vary among sites. Although most sites showed negligible shifts towards earlier timing, statistically significant changes were detected in three systems. Overall, winter sea surface temperature, spring and fall transition dates, and annual run size were the strongest predictors of run initiation and median dates, while a combination of within-season and seasonal-lag effects influenced run end and duration timing. Disparate results observed across the 12 spawning runs suggest that regional environmental processes were not consistent drivers of phenology and local environmental and ecological conditions may be more important. Additional years of data to extend time series and monitoring of Alewife timing and movements in near shore habitats may provide important information about staging behaviors just before adults transition between ocean and freshwater habitats.

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RELEVANT EXCERPTS FOR SLOUGH POND:

Spawning timing and migration may not be triggered by the same environmental and ecological processes or scales; for example, fish may arrive at spawning grounds at different times, but initial spawning occurs at the same time. Alewife also do not necessarily adhere to the paradigm of single migratory movements to spawning locations; rather, they may move in and out of spawning locations several times within a season (McCartin et al. 2019), which may con-found some of our results. This behavioral plasticity may allow Alewife to take advantage of and move in response to optimal short-term (daily or even hourly) conditions at local scales (McCartin et al. 2019).

Shifts in population size and demographics through restoration and management activities can also act to confound phenological responses due to changes in the sizes and ages of fish in the population (Tillotson and Quinn2018).

Although runs did not demonstrate the predicted shift to earlier migrations with the regional warming that has occurred recently, broad scale drivers did explain variation in timing over the study period. Run initiation and peak metrics were earlier when minimum winter SST was warmer and winter duration was shorter (either through later fall transition dates during the previous year or earlier spring transition dates). Run initiation was also earlier when run sizes were larger, indicating that changes in abundance and population restoration may confound climate-induced signals of phenology (Tillotson and Quinn2018). Peak run timing was influenced by changes in the GSI and is consistent with prior studies in the region showing that fish population distributions are sensitive to changes in bottom water temperatures (Nye et al. 2011).

Changes in the migratory behavior of Alewife and other anadromous species in response to broad scale climate and local-scale restoration activities have important ecological and management implications (Peer and Miller 2014). First, if Alewife migrate to spawning grounds sooner, they may stimulate changes in production because they deliver marine-derived nutrients into freshwater systems earlier (Durbin et al. 1979). Second, if the temperatures at the freshwater spawning grounds are not yet optimal under ea-lier migration, longer residence times in spawning ponds may result in changes in the zooplankton base through top-down control (Brooks and Dodson 1965; Mattocks 2016). Third, Alewife may escape a window of vulnerability if predators, such as Striped Bass Morone saxatilis, move inshore from their ocean overwintering grounds at different times in the season, thereby affecting predatory demand and population dynamics (Furey et al. 2018).

Further studies are needed to evaluate how changes in Alewife migration patterns scale from daily to seasonal patterns through direct evaluation and with the inclusion of effects from passage impediments, restoration actions, and local population traits (e.g., genetic diversity and thermal tolerances). The results of this study emphasize the need to develop adaptive management strategies that account for temporal changes in adult Alewife spawning migration patterns resulting from climate and restoration and that are routinely updated as new information becomes available. As the regional climate continues to change, expanded monitoring, particularly in near shore habitats where fish may stage before transitioning between ocean and freshwater habitats, will be vital for detecting whether populations are adapting in place, approaching a critical threshold, or becoming more at risk for phenological mismatches.