1. Overview of current ecosystem baseline

Collecting environmental and fish community structure data for the past ten years has given us a deeper insight into Casco Bay’s nearshore ecosystem dynamics. To date, we have caught more than 50 unique species of fish and crustaceans in our seine sampling program. The eight most frequently captured species (caught in at least 10% of all sampling attempts) are green crab, Atlantic silverside, winter flounder, mummichog, alewife, Atlantic herring, Atlantic tomcod, and American sand lance. Some of these species are year-round residents of nearshore waters, like green crab, American sand lance, mummichog, and Atlantic silverside. Other species, like winter flounder and Atlantic herring, are dependent on Casco Bay and similar estuarine environments as nursery areas for juveniles. As adults, they will make regular seasonal migrations using the Gulf of Maine’s inshore areas. A third group of species like Atlantic tomcod and alewife are diadromous, meaning they spawn in the fresh waters of coastal rivers and migrate to the ocean as adults. The populations of all migrant species will be affected not only by environmental conditions in Casco Bay but also in the other riverine and oceanic habitats they use. The status of the wider Gulf of Maine ecosystem is therefore dependent on the health of all its components and is particularly dependent on highly utilized and resource-rich nearshore habitats like Casco Bay.

Most of the species we commonly observe in our seine samples are in the southern half of their native range, meaning their tolerance for warming waters may be limited. Notable exceptions include green crabs, which are native to the Mediterranean region, and Atlantic silversides and mummichogs, which are frequently found in nearshore waters as far south as Florida. Species that are better adapted to colder waters may suffer severe population declines or be forced out of their historical habitat as it warms.

With ten years of data on the Casco Bay ecosystem, we can analyze how the abundance, distribution, and growth of our commonly sampled species may have shifted with changing environmental conditions. Using sea surface temperature data from the Portland Harbor NOAA tide gauge as an approximation of all of Casco Bay’s nearshore temperatures, we have grouped our data into the five coldest (2014-2015, 2017-2019) and five warmest (2016, 2020-2023) years. There are pronounced differences in the relative abundances of fish species between colder and warmer periods (Figure 1). In colder years, Atlantic herring is the most commonly caught fish, followed by Atlantic silverside. This relationship flips in warmer years. Atlantic tomcod also appears to be sensitive to warmer temperatures and are more abundant in colder years. These changes in relative abundance could be driven by any number of factors linked to temperature, such as food and habitat availability, changes in current patterns, or changes in fish reproductive ability.

It is important to note that these results may not directly reflect the population size of these fish species. Our perception of a species’ abundance is dependent on our ability to collect representative samples in all areas in which they are present and all times in which they are present. A summertime-only nearshore seine survey cannot do this, and therefore we cannot use our data to directly assess the population sizes of the fish species we observe. However, these fish community structure changes are meaningful. They may reflect shifts in the spatial or temporal habitat usage patterns we have historically noted when observing Casco Bay fishes.

1. Emergent Trends

There is clear evidence that warming ocean temperatures in the Gulf of Maine have had adverse effects on cold-adapted native species, particularly Atlantic tomcod and Atlantic herring. In warm years, tomcod and herring have decreased abundance in seine samples and leave the survey area earlier in the season (Figures 2 and 3). Field data collected during our seining operations indicated that tomcod and herring were present in waters significantly colder than the mean temperature across all seines, indicating potential avoidance of warmer waters. Analysis of herring growth rates revealed a trend of faster growth and larger fish in colder years. Though Atlantic herring are migrants and are influenced by environmental conditions in a large area of the North Atlantic Ocean, suboptimal conditions in estuarine nursery areas and associated negative impacts on critical early life-history stages may have an outsized effect on the population. Monitoring the population within Casco Bay could give us insight into future fluctuations in herring abundance.

We are also tracking the recent appearance and increase in abundance of permit, crevalle jack, white mullet, and summer flounder in Casco Bay (Figure 4). These fish are not native to the Gulf of Maine, and their distribution has historically been bounded to the north by Cape Cod. As the influence of the cold Labrador Current decreases and temperatures rise within the Gulf of Maine, warm-adapted species carried to our region by the Gulf Stream Current may survive the winters and become permanent residents. These non-native species may outcompete native species for food and resources in a warming environment, and it will be important to monitor their populations.

Figures

Side note: happy to adjust color palettes, image dimensions, label sizes, or provide high-res TIFs/PDFs as needed. Let me know.

A screenshot of a computer screen

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Figure 1. Nearshore Casco Bay ecosystem community structure in the five coldest (2014-2015, 2017-2019) and five warmest (2016, 2020-2023) years of CBASS seine survey data collection, as illustrated by scaled indices of relative abundance for the top 8 most frequently caught fish and crustacean species.

A chart with different colored squares

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Figure 2. Atlantic herring relative abundance during CBASS seine survey operations, 2014-2023. The color of the year on the vertical axis indicates whether that year was in the top 5 warmest (red) or the top 5 coldest (blue) years of the time series. Each colored cell indicates the relative abundance of Atlantic herring for one week of the sampling season. Gray indicates that seine sampling was conducted, but no herring were observed. Cooler colors (purples and blues) indicate that relatively few herring were caught in that week, while warmer colors (yellows) indicate that relatively many herring were caught in that week.

A chart with different colored squares

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Figure 3. Atlantic tomcod relative abundance during CBASS seine survey operations, 2014-2023. The color of the year on the vertical axis indicates whether that year was in the top 5 warmest (red) or the top 5 coldest (blue) years of the time series. Each colored cell indicates the relative abundance of Atlantic tomcod for one week of the sampling season. Gray indicates that seine sampling was conducted, but no tomcod were observed. Cooler colors (purples and blues) indicate that relatively few tomcod were caught in that week, while warmer colors (yellows) indicate that relatively many tomcod were caught in that week.

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Figure 4. “Southern” species (white mullet, permit, crevalle jack, and summer flounder) relative abundance during CBASS seine survey operations, 2014-2023. The color of the year on the vertical axis indicates whether that year was in the top 5 warmest (red) or the top 5 coldest (blue) years of the time series. Each colored cell indicates the relative abundance of all southern species for one week of the sampling season. Gray indicates that seine sampling was conducted, but no southern species were observed. Cooler colors (purples and blues) indicate that relatively few southern species were caught in that week, while warmer colors (yellows) indicate that relatively many southern species were caught in that week.