Report Title: Synergy of the historical record, metapopulation dynamics, and disease resistance in native oyster restoration

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Native oyster populations have been decimated worldwide due to overfishing, eutrophication, and oyster reef degradation. In the Chesapeake Bay abundance of the native Eastern Oyster, *Crassostrea virginica*, has declined to less than 1percent of historical values, leading to considerable, expensive attempts to restore native oyster populations at well over 1,000 reefs bay-wide.

Previously it was concluded that successful restoration of the native oyster is improbable, leading to consideration of an introduction of non-native oysters. Today, the echoes of this argument are being used to discount ecological restoration efforts and promote fishery subsidies.

Recently, however, populations of native *C. virginica* have persisted on natural and alternative oyster reefs constructed in restoration efforts and protected from exploitation in Delaware Bay, North Carolina sounds, and the Chesapeake Bay.

The range of restoration strategies has included emphasis on disease resistance, addition of substrate and three-dimensional reef structure, extant oyster abundance, broodstock enhancement and elimination of fishing pressure, metapopulation connectivity, and habitat suitability. In these restoration efforts, unfished *C. virginica* populations overcame disease challenges and persisted when provided reefs of superior quality, which enhanced growth and survival. Moreover, some native oyster populations have evolved disease resistance in mesohaline and polyhaline waters of Chesapeake Bay, signifying that native oyster restoration is not doomed.

In 2007 and 2008, a complex of reefs was constructed by the U.S. Army Corps of Engineers in the Lynnhaven River subestuary, the southernmost tributary of Chesapeake Bay. Several of the reefs were seeded with millions of spat on shell these reefs were selected based on a combination of historical information coupled with a modern-day hydrodynamic model.

The model was used to predict oyster larval movement patterns in the river and where it would be best to stock oysters to maximize recruitment in the Lynnhaven River. It was previously concluded that restoration potential in the Lynnhaven River subestuary was limited based on physical conditions, disease challenge, and extant oyster abundance. The Army Corps believed otherwise, based on the history of the river and the model outputs, along with promising evidence found during a survey of the river. Our surveys discovered several small, undisturbed subtidal reefs in the Lynnhaven River that had large populations of oysters on them, providing evidence that large-scale restoration, if properly executed, could work.

A recent study demonstrates how the integration of diverse sources of information can be used to determine suitable locations for oyster restoration efforts. This study evaluated previously unknown historical data from the 1800s; used field surveys of oyster recruitment and abundance, physical conditions, and disease presence; and assessed simulations from biophysical models identifying potential restoration reefs in the metapopulation of the Lynnhaven River.

Historical records of oyster abundance in the Lynnhaven River subestuary consistently provide evidence of the high abundance and quality of oyster reefs in the system. The restored reefs were surveyed four-five years post-construction in 2012. These field surveys indicated that there was high recruitment and oyster abundance throughout all sampled parts of the subestuary. Adult oyster density on all constructed reefs surpassed the threshold (15 adult oysters m^{-2}) for minimally successful performance of constructed oyster reefs set by the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team. In addition, three of the reefs exceeded the target (50 adult oysters m^{-2}) for fully successful performance, two of the reefs were at the target, and the remaining reef complex was between the threshold and target.

Adult oyster biomass on all constructed reefs also surpassed the threshold (15 g Ash Free Dry Mass [AFDM] m^{-2} of adult biomass) for successful performance of constructed oyster reefs. As expected from previous findings on the Corps' sanctuary reefs in the Great Wicomico River, oyster density was higher on high-relief reef than on low-relief reef in all locations. The results also indicate that the oyster populations in the high-salinity waters of Lynnhaven are relatively resistant to diseases despite strong disease challenge.

Finally, it was estimated that there was a total oyster abundance of nearly 16 million oysters on the constructed reefs, resulting from the Corps' sanctuary reef construction. There were no live oysters at any of the reef sites pre-restoration, so this represents a dramatic increase in the Lynnhaven River oyster population. Some of these oysters are 6-7 inches long, far past the size of 3 inches, which is thought by many to be the size at which most of our native oysters die from disease.

Due to the long closure of the oyster fishery, as well as the salty water of the Lynnhaven River that allows the two oyster diseases MSX and Dermo to flourish, the Lynnhaven oysters were permitted to undergo natural selection for disease resistance. Today, the local wild Lynnhaven oyster is one of the most, if not the most, disease resistant oyster strain in the Chesapeake Bay. While not immune, many now live well past the age and size where disease would typically kill them in the past.

These findings demonstrate that assumptions about habitat suitability for oyster restoration based on individual processes can be severely flawed, and that in-depth examination of multiple processes and sources of information are required for oyster reef restoration plans to maximize success. In addition, these results indicate that oyster restoration has great potential in the Lynnhaven River subestuary and presents justification of the recent large-scale oyster restoration efforts in the system.