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Observations on the Expansion of a Relict Population of Eastern Oysters (*Crassostrea virginica*) in a Maine Estuary: Implications for Climate Change and Restoration

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Abstract - The Gulf of Maine has undergone dramatic physiographic and oceanographic changes over the last several millenia resulting in some unusual biogeographic consequences. One is that there are pockets of Virginian species, including *Crassostra virginica* (Eastern Oyster), that survive in isolated warm water pockets, usually at the heads of estuaries. These small and vulnerable populations need documentation, protection, and restoration in order to preserve their genetic characteristics and ecological services. In this contribution, we describe the circumstances whereby tidal restoration made available 2.5 linear km of new habitat area to the relict oyster population of the Marsh River, ME, the northernmost documented native oyster population in the United States. Oysters recruited to the new habitat quickly, demonstrating the restoration potential of isolated, relict populations. The resultant larger population size and areal extent should provide increased stability and survivability of the oyster and its associated community. These observations have implications for both the restoration potential of relict oyster populations and the consequences of climate change.

Eight thousand years ago, the Gulf of Maine was a very different place than it is today (Bousfield and Thomas 1975, Larsen 2004, Shaw et al. 2002). Sea level was lower, and tides were minimal or non-existent, resulting in a Gulf that was lagoonal in nature (Campbell 1986). This condition allowed for warm summer water temperatures that were suitable for colonization by warm temperate (Virginian) species from the south. During this hypsothermal period, the distribution of warm temperate species was continuous from the mid-Atlantic to the Gulf of St. Lawrence (Bousfield and Thomas 1975). As sea level rose in succeeding millennia and larger and larger tides developed (Grant 1970, Greenberg et al. 2012), the surface waters of the Gulf cooled and warm temperate species were increasingly restricted in their range within the Gulf of Maine. The populations of several species became disjunct from the main population centers in the mid-Atlantic region, and from one another, with the result that groupings of warm temperate species are now limited to isolated pockets, called Virginian refugia, where summer water temperatures in most, but not all, years still reach levels (mid-20s °C) sufficient for the reproduction of these species with southern affinities. The Virginian refugia are usually located near the heads of estuaries and are largely confined to mid-coast Maine, particularly to the complex Sheepscot estuary and its tributaries (Fig. 1). *Crassostrea virginica* Gmelin **(**Eastern Oyster) is the most important and characteristic of these species. These are ancient, natural populations of oysters that were present well before the introduction of *C. virginica* to a few lower estuarine sites by the aquaculture industry in the early 1970s. DNA analyses are anticipated to establish the genetic relationship of the natural and aquacultural oysters.

There is a critical need for increased knowledge of the native oyster populations in the Gulf of Maine because they are at risk for several reasons (Beck et al. 2009). Several populations are surely as yet undiscovered and undocumented and, hence, can be destroyed unknowingly. The population sizes are small and are located in confined habitats where

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they can be extinguished by relatively minor environmental perturbations including harvesting, chemical spills, upland erosion, hydrodynamic alterations, and disease. As these relict populations have been isolated from the main populations for a long time, perhaps hundreds or even thousands of years, these populations may provide a divergent genetic resource that will be significant in the face of climate change. In addition, it is important to realize that oysters and their associated faunal community are, or are potentially, the characteristic community of upper estuaries in Maine. These are the same areas where we would expect the first signals of climate change to be observed in the coastal zone because the freshwaters entering the estuaries will warm faster than the tidally mixed seawater entering estuarine mouths and because the hydrology of these systems is highly responsive to change in the timing and magnitude of freshwater inputs (C. Hebson, Maine Department of Transportation, Augusta, ME, pers. comm.). These oyster communities will provide a sensitive sentinel of climate change. Thus, the identification, protection, restoration, and expansion of the relict Maine oyster populations will have important implications for the biodiversity and ecological services in Maine estuaries (Coen et al. 2007) both currently and in response to future climate change.

The Marsh River/Deer Meadow Brook oyster population. The Marsh River/Deer Meadow Brook oyster population is considered the northernmost native oyster population in the United States (Cowger 1975). The existence of this site is well documented, although little is known about the ecology of the system or the biology of the resident oysters. Other relict oyster populations are suspected to exist and are being explored. There was a commercial oyster harvest in the Marsh River until the 1960s (Cowger 1975). The area was declared a Maine Department of Marine Resources Conservation Area in 1968 to protect the oyster population from overharvesting, and much of the surrounding land is now undeveloped and protected by public and private conservation easements. The site has been registered by the Maine Critical Areas Program (Cowger 1975) because of the presence of native oysters. The oyster, together with a concentration of other natural attributes in this relatively undeveloped area, led to the site's nomination as a NOAA estuarine sanctuary (MSPO 1981). A 2008 video survey of the area by Larsen and Barker (unpublished) found healthy, multi-year-class populations of oysters, many growing vertically, in high densities wherever the bottom was suitable along a 3.25-km reach of the river. Nevertheless, we consider this population to be at risk because of the limited bottom available for oyster settlement and due to the small areal extent of the oyster's distribution. The specific distribution and abundance of natural oysters in the Marsh River system have not been documented due, in part, to lack of visibility in the turbid water.

The Formation of Sherman Marsh. In 1935, a causeway was constructed to carry US Route 1 across the upper section of the Marsh River (Fig. 1). This barrier terminated the flow of salt water to the upper 2.5 km of the Marsh River and converted the former intertidal marshland into the 90-ha Sherman Lake. Over seven inches of rain fell in the vicinity on 8–9 October 2005. This event, with a return period of about 50 years (C. Hebson, pers. comm.), breached the causeway causing Sherman Lake to drain and allowing limited tidal flow to return once again after a 70-year hiatus. Subsequently, other storm events, especially the Patriots Day storm of 16 April 2007, lowered and widened the sill remaining at the causeway and significantly increased tidal flow above the causeway. Finally, restoration efforts opened and stabilized the breach until the natural tidal exchange was almost completely reestablished in fall 2008. The return of tidal flow to Sherman Marsh was therefore a three-stage process. In the fall of 2005, the breach allowed limited tidal exchange with an approximately 1-m tide at the upper half of the normal natural tidal range. By the fall of 2007, the additional erosion of the causeway resulted in a 1.5-m tide. Finally, in the fall of 2008, permanent stabilization of the marsh outlet created a nearly complete tidal exchange with the exception that, due to a hard control elevation at the outlet, the water drains to only 1.23 m below mean sea level in the marsh, or approximately 0.4 m higher than the external mean low water (NAVD) (C. Hebson, pers. comm.).

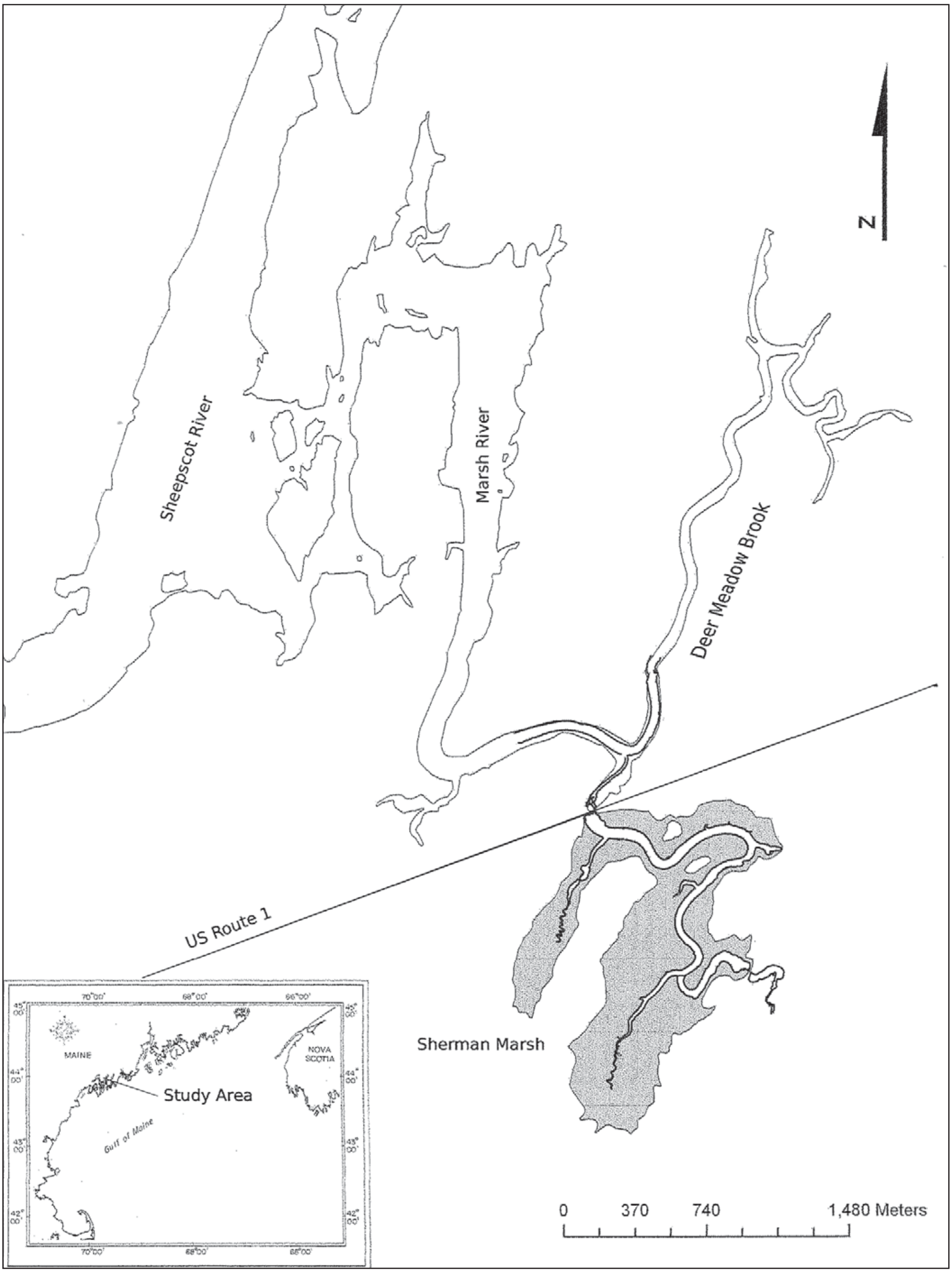

Figure 1. Location of the relict Marsh River oyster population, indicating the Marsh River, Deer Meadow Brook, and Sherman Marsh, the former Sherman Lake. The shaded area represents the extent of the newly restored Sherman Marsh.

Recruitment and Establishment of Oysters in Sherman Marsh. On 10 October 2008, one of us (K.A. Wilson) noticed young oysters on a rock ledge approximately 1.5 km upstream from the breached causeway (Fig. 2). These individuals were found dead the following year when the increasing tidal range resulted in the site becoming intertidal. Examination of photographs of these oysters indicated that they were two or three years old. If that age estimation is correct, the oysters recruited from the main Marsh River population in summer of 2007 after the Patriot's Day storm of April 2007 or even in summer 2006 after the initial breach in the autumn of 2005. Further sampling and measurement will be undertaken to better fix the date of initial recruitment as well as the pattern of continuing recruitment.

Subsequent surveys in 2010 and 2011 determined that oysters are now established on nearly every piece of suitable substrate in Sherman Marsh, including ledges, rocks, logs, gravel pockets, and miscellaneous debris. We are presently unable to estimate the size of the Sherman Marsh oyster population because of the very patchy distribution of the suitable habitat. The total amount of new habitat in Sherman Marsh, however, unquestionably remains small, perhaps only tens of square meters. We expect that the amount of suitable oyster habitat in Sherman Marsh will increase over time, however, as tidal action continues to flush out soft sediment associated with 70 years of lacustrine conditions. Salinity and temperature far up the river in Sherman Marsh are suitable for oyster survival and growth. We have observed salinities of 24 psu and temperatures of over 23 °C in August 2010. The opening of this 2.5 linear km of potential oyster habitat, with conducive salinities and temperatures, has increased the available space for the Marsh River/Deer Meadow Brook native oyster population by 75%. The limiting factor remains the restricted and irregular

Figure 2. Young *Crassostrea virginica* (Eastern Oyster) growing in Sherman Marsh on a subtidal rock ledge 1.5 km above the original causeway as photographed in October 2008. (Photograph © K.A. Wilson).

distribution of firm substrates for oyster sets, which suggests that the site may be suitable for restoration projects to accelerate the development of favorable oyster bottom.

In summary, the breaching of the Marsh River causeway converted 2.5 km of lacustrine environment into a marine environment. Salinities and temperature are suitable for oyster set and survival and, indeed, oysters recruited to the new habitat a very short time after the causeway burst. Population development is limited at present, however, by the sparse firm substrate available. The transition is ongoing, and we observe a natural progression towards increasing oyster habitat. The process could be greatly accelerated by restoration efforts targeted at returning the estuary to its natural pre-1935 state, thereby conserving and protecting this northernmost native Eastern Oyster population in the United States. This contribution documents that the breach of the US Route 1 causeway opened new habitat for the relict Marsh River/Deer Meadow Brook oyster population, expanded the local range, and increased the population size. All of these factors increase the survivability of this unique natural resource and the ecological services it provides. In addition, they demonstrate the potential for efficacious restoration efforts at similar sites.

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