EXECUTIVE SUMMARY

Global climate models suggest that sea surface temperatures in the North Atlantic will increase by 24ºC by 2090 due to anthropogenic increases in greenhouse gases emissions. Our study examined sea surface temperature changes and their impacts on the distribution of 33 commercially important marine species in the coastal waters Atlantic Canada and New England that are likely to accompany this warming. We also determined the most vulnerable characteristic or life stage of each species in terms of thermal parameters and ranked species with respect to their vulnerability to temperature change and barriers to adaptation.

We used output from an ensemble of four coupled general circulation models (AOGCM) and two climate forcing scenarios, A2 and B2, developed for the IPCC Third Assessment Report to predict future sea surface temperatures (SSTs) on the Northwest Atlantic. AOGCMs can be regionally variable, but our assessment revealed an acceptable consistency when downscaled model output was compared within three large marine ecosystems (LMEs) in our study area: the NewfoundlandLabrador Shelf, Scotia Shelf, and the Northeast U.S. Continental Shelf. Differences in projections within the model ensemble were greater than differences between the scenarios A2 and B2 for a single model, revealing the importance of using multiple models in impact and adaptation studies. We found that there will be major differences in the timing of SST increases. In the waters of the Northeast U.S. Continental Shelf there will be roughly equivalent increases in summer and winter SSTs, but greater winter warming in the north will reduce seasonality on the Scotia and NewfoundlandLabrador Shelves. At a finer scale, we identified areas where notable increases in SSTs are likely to occur: the Gulf of St. Lawrence, the region immediately north of Cape Hatteras, North Carolina, and on the northeast Labrador coast. Although the coarse resolution of AOGCMs prevents assessment of many characteristics of ocean circulation that cause local or shortterm variability in ocean temperatures our analyses indicated that sea surface temperature increases will be greater than that natural variability.

To investigate potential changes in spatial distribution of species we used present distribution, the best available indicator of a species' climatic requirements, or "bioclimate envelope". As climate changes, species are likely to redistribute according to preferred climatic conditions. Our results indicated that the future sea surface temperatures associated with a 4°C rise in global temperature will cause in a change in distribution of every species examined. Species fell into four general groups based on broad degree and pattern of thermal habitat change:

1. Greatest thermal habitat loss (Gulf of St. Lawrence and waters off Nova Scotia, Newfoundland, and Labrador) – serrated wrack, capelin, Atlantic salmon

2. Lesser thermal habitat loss (southern Gulf of Maine and southward, southern Gulf of St. Lawrence, and occasionally waters off southern Nova Scotia) – knotted wrack, the kelps, *Calanus finmarchicus*, northern shrimp, green sea urchin, and American plaice

3. Least thermal habitat loss (southern part of species range, approximately Cape Cod southward) – rockweed, black clam, Atlantic rock crab, eastern oyster, American lobster, Atlantic longfin squid, quahog, soft-shelled clam, blue mussel, Atlantic deep-sea scallop,

Atlantic wolffish, Atlantic menhaden, herring, cod, halibut, haddock, and silver hake

4. Thermal habitat gain in addition to loss in the southern part of species range (gains in Gulf of St. Lawrence and variable in waters off Nova Scotia, Newfoundland, and Labrador) – blue crab, green crab, Asian shore crag, and common periwinkle

Relative sensitivity, or vulnerability, of these species was considered a function of mobility (ability to disperse or migrate) at each life history stage and eurythermal capacity (the limits of individuals or populations to tolerate warming temperatures). The algal species ranked among those most vulnerable to climate change. In general fishes were among the least vulnerable species. However, Atlantic salmon and capelin ranked as very vulnerable species. Invertebrate species were not at either extreme, but ranked from above average sensitivity to among the least sensitive.

The trend from greatest loss to gain of thermal habitat corresponded with increasing eurythermal capacity and to a distribution from a more northerly to a more southerly nature. Thus, we conclude that species most negatively impacted by climate change in terms of loss of thermal habitat will be those with low eurythermal capacity and a more northerly distribution since they have less potential to tolerate warmer temperatures or to retreat or expand northward as waters warm.

Change in thermal habitat of our target species will have consequences on harvesting varying from none to substantial. Negative commercial impacts will be much greater in harvested populations in U.S waters off New England and in the mid-Atlantic Bight than in Canadian populations. Knotted wrack may be affected negatively in the southern Gulf of St. Lawrence. Harvesting of the kelp *Laminaria digitata* may cease in the southern Gulf of St. Lawrence. The Canadian eastern oyster industry may expand. The common periwinkle fishery may decline in the Gulf of Maine and cease southward. Warming temperatures should not affect directly the harvest of soft-shelled clams and blue mussels but may allow the invasive Asian shore crab to expand throughout the Canadian Atlantic causing serious population depletions in both bivalve species. Likewise, Atlantic deep-sea scallops should be able to tolerate predicted temperature shifts but natural and cultured scallops may suffer from increased colonization by exotic species and algal blooms, toxic or otherwise. The important Atlantic menhaden fishery may end in southern U.S. states. In Canada the American plaice fishery may be impacted in the southern Gulf of St. Lawrence and perhaps elsewhere. Fishing for capelin will be negatively affected in most Canadian regions - Labrador, southern Grand Bank, perhaps the western Grand Bank and off southern Newfoundland, the Gulf of St. Lawrence, and the Cabot Strait region of Cape Breton Island. There likely will be no impact on commercial Atlantic salmon fisheries as they are closed throughout the western North Atlantic and have little chance of reopening in the coming decades. Climate change impacts on the fish probably will preclude recovery of the stocks to levels supporting commercial fisheries. Increased sea surface temperatures may benefit aquaculture in the inner Bay of Fundy and enable expansion of salmon aquaculture into waters of northern Nova Scotia, southern Newfoundland, and the Gulf of St. Lawrence. However, increased sea temperatures will seriously hinder attempts at the recovery of endangered Atlantic salmon populations, and the restoration of historic salmon runs where populations have been extirpated.

Results of this project and a stakeholder workshop have been disseminated to the Canadian public via conference presentations, a project web site and local and regional newspapers and television. Related climate change research by the team was disseminated through a press conference which generated national, local and regional newspapers and television coverage, a publicly distributed brochure, and an online white paper. Scientific articles arising from our research will be published following submission of the final project report.