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Research paper

Impact of bottom water temperature change on the southernmost snow crab fishery in the Atlantic Ocean

Ben Zisserson*, Adam Cook

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2, Canada

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ABSTRACT

Snow crab populations are found in the Northern Atlantic, Arctic and Pacific Oceans. Snow crab are generally considered to be a stenothermic species with distributions constrained by the available thermal habitat. Crab fishing area 4X on the western Scotian Shelf is at the southernmost extent of Snow Crab distribution in the Northwest Atlantic. Bottom temperatures in this area provide very limited snow crab habitat. An incursion of warm slope waters flooded the western Scotian Shelf in 2011/2012 and created positive temperature anomalies. These warmer bottom temperatures appeared to have had a negative impact on some life stages of snow crab in local populations, with juvenile stages being the most affected. Evidence of this decrease was supported by various fisheries independent and dependent data sources. Though 4X snow crab populations are now increasing, likely due to immigration from an adjacent snow crab fishing area, this warm water event was very detrimental to the commercial fishery in the area.

1. Introduction

Climate change has become a prevailing feature across many ecosystems. Of those factors expected to change, temperature receives particular attention in aquatic environments as it is known to influence numerous biological processes. These influences range from the individual organism to a population level. In marine ecosystems, increased temperatures have resulted in changing phenology (Hughes, 2000) and shifts in distribution (Perry et al., 2005a,b; Nye et al., 2009) for some species. Long term changes in mean state of climatology will likely have direct and prolonged effects on marine populations; however the influence of increased variability and frequency of extreme events may play an even greater role in altering a population's productivity (Rijnsdorp et al., 2009). Species at the limits of their geographic range may be more susceptible to increasingly variable environments (Sexton et al., 2009). Furthermore, widespread socioeconomic impacts can result from affected commercially exploited species.

Snow crab (*Chionoectes opilio*) populations are found in the Northern Atlantic, Arctic and Pacific Oceans and inhabit a wide range of habitats throughout their geographic bounds. Across their range they are the target of commercial fisheries. The Scotian Shelf snow crab fishery currently represents one of the highest value fisheries in the Fisheries and Oceans Canada Maritimes region (http://www.dfo-mpo.gc.ca/stats/stats-eng.htm) with annual landings exceeding 10,000 mt corresponding to a landed value in excess of 68 million dollar (DFO, 2014). There are four snow crab fishing areas (CFA's) on the Scotian Shelf (Fig. 1). One of these areas, CFA/NAFO 4X, located within the Gulf of Maine/western Scotian Shelf, represents the species' southernmost geographic range and fishery.

Snow crab are generally considered to be a cold-water stenothermic species with distributions constrained by the available thermal habitat and are therefore particularly susceptible to warming events. Specific work on the Scotian Shelf has shown that temperatures between −1 to 6 °C generally bound their habitat (Choi et al., 2013). Further support from lab based experiments show that temperatures above 7 °C result in a negative metabolic state as the energy required for catabolic processes surpass those available through anabolism (Foyle et al., 1989). Here we report on the impact of the warming event of 2012 in CFA 4X, show the relative impact of the high temperature anomaly on juvenile and adult snow crab abundance and impacts on commercial harvesting. Additionally, we provide results from a survey with broader spatial coverage, which yield the evidence to support an increase in snow crab mortality rather than emigration during the warming event.

1.1. Regional climatology

Bottom temperatures on the Western Scotia Shelf – 4X area are generally characterized as being warmer than are considered ideal for snow crab for much of the year (Hebert et al., 2013). In this area there

* Corresponding author at: 1 Challenger Drive, Dartmouth, Nova Scotia, B2Y 4A2, Canada.
E-mail addresses: Ben.Zisserson@dfo-mpo.gc.ca (B. Zisserson), Adam.Cook@dfo-mpo.gc.ca (A. Cook).

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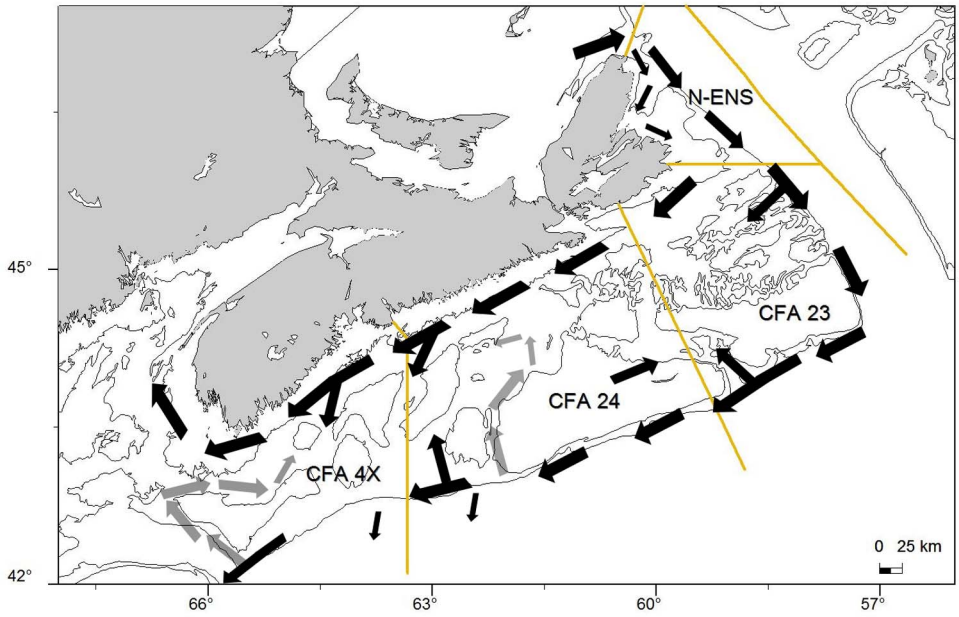

Fig. 1. Scotian Shelf with Crab Fishing Areas (CFA's). Black arrows represent cold water currents and grey arrows represent warm water currents. Yellow lines delimit each crab fishing area (N-ENS, 23, 24, 4X). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

are two predominant oceanographic currents that characterize the thermal environment (Fig. 1). First, the warm slope waters from the shelf edge are pushed through the Northeast Channel east of George's Bank which creates several warm water gyres. The cold water of the Nova Scotian Current results from an outflow of cold water from the Gulf of St Lawrence and follows along the Nova Scotian coastline creating a narrow band of cold water on the inshore regions of the western Scotian Shelf with incursions into two relatively small basins, Lahave and Roseway. Snow crab (and the directed snow crab fishery) exist within this relatively narrow expanse of cold bottom water in CFA 4X. These circulation patterns do change seasonally (Hannah et al., 2000) and inter-annually (Smith, 1989; Petrie, 2007), thereby affecting the volume of cold water habitat available to snow crab.

In late 2011 through to 2012, warm slope waters flooded the western Scotian Shelf (Gawarkiewicz et al., 2012; Choi et al., 2013), creating positive anomalies in bottom temperature. This event was unpredicted and appeared to result from a northwesterly diversion of the Gulf Stream onto the continental shelf (D. Brickman, DFO pers

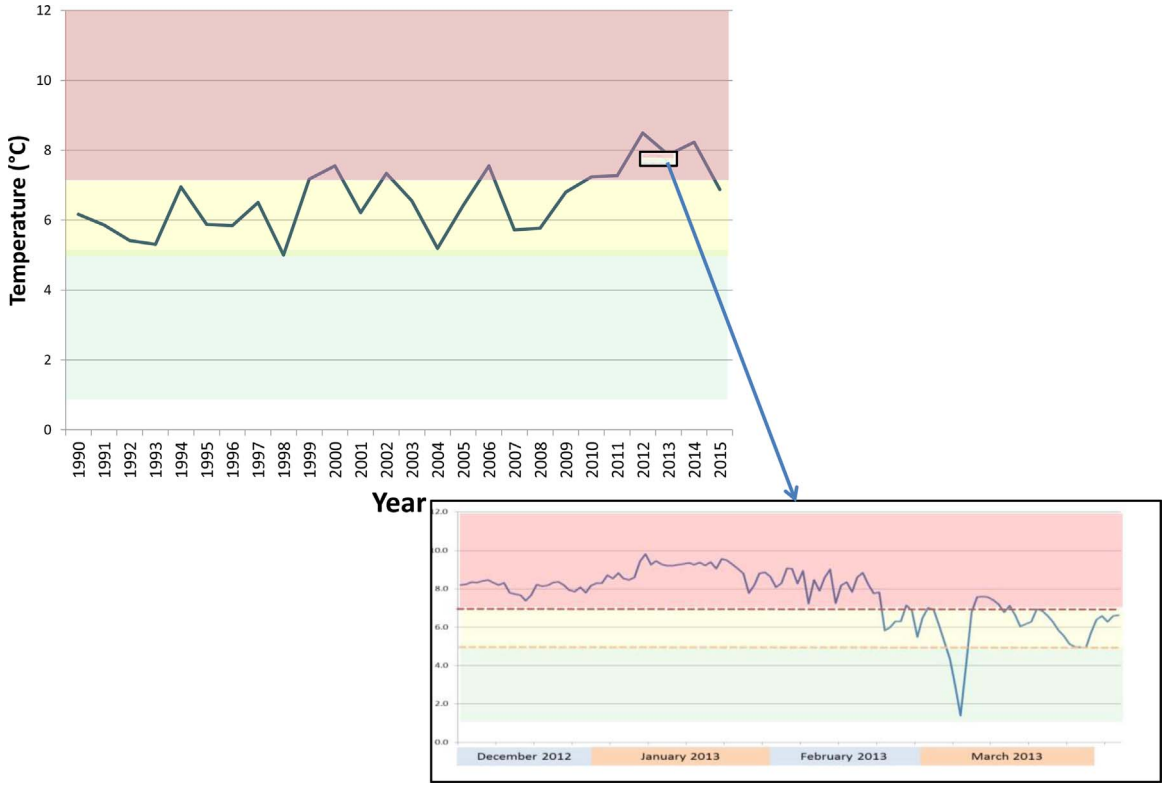

Fig. 2. Annual summer mean bottom temperatures for 4X from ecosystem survey with detailed daily mean bottom temperatures from snow crab traps in 4X for more limited temporal and geographic extent (inset). Area shaded in green denotes ideal, yellow is marginal, and red is considered unsuitable temperature conditions for snow crab. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)