## Title:

Rebuttal to Frank et al 2016

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## Abstract

## Introduction

Forage fish play a crucial role in many ecosystems, acting as a conduit of energy between lower trophic levels and large vertebrate predators. Forage fish are small shoaling species that characteristically have rapid growth, short life expectancies, and population responses tightly linked to environmental control. These characteristics lead this group of species to exhibit boom and bust dynamics, i.e. their abundances change rapidly and substantially and undergo phases of extremely high and extremely low abundances (Soutar & Issacs 1969, Schwartzlose et al. 1999, Chavez et al. 2003, Alheit et al. 2009, Pikitch et al. 2012).

Capelin is the focal forage species in ecosystems of the northern Atlantic Ocean (Templeman 1948, Jangaard 1974, Vilhjálmsson 1994, Carscadden et al. 2001). The three most important capelin populations in the North Atlantic are in the Barents Sea, off Iceland, and off Newfoundland and Labrador (Canada). The Barents Sea capelin stock underwent three collapses during the last 4 decades, during the mid- to late 1980s, mid-1990s, and mid-2000s. The size of the stock fluctuated between 3 - 7 million tonnes during the boom and around 200 thousand tonnes during the bust phases. There is general agreement that ecosystem changes were the driving forces behind these dynamics (Gjøsæter et al. 2009). The Icelandic capelin stock underwent similar dynamics, with three bust phases in the last 4 decades, in the early 1980s, in the early 1990s, and during most of the 2000s. The size of the stock was around 1.5 - 2 million tonnes during the boom and between 100 and 500 thousand tonnes during the bust phases (ICES 2017).The first two cases were due to a combination of poor recruitment and the stock being easily available to the fishing fleet, while the last case was likely associated to a climate-related shift in distribution (Pálsson et al. 2012, Carscadden et al. 2013).

Fisheries and Oceans Canada is responsible for the assessment of the Newfoundland and Labrador capelin stock; it has concluded that there was an order of magnitude decline in the stock in the early 1990s, and that capelin abundance declined to less than 1% of historic levels in 2010 (DFO 1994, Miller 1994, 1997, DFO 2008, 2010, 2013, 2015). The size of the stock fluctuated between 2 - 6 million tonnes prior to 1991, and between 25 and 900 thousand tonnes during the ensuing period (DFO 2015).This decline was concomitant with drastic changes in the ecosystem during the late 1980s and early 1990s (Hutchings & Myers 1994, Gomes et al. 1995, Lilly et al. 2000, Rice 2002, Koen-Alonso et al. 2010, Hammill et al. 2011, Pedersen et al. 2017), including major changes in the biology and ecology of capelin (Carscadden & Nakashima 1997, Carscadden et al. 2001, Nakashima & Wheeler 2002, DFO 2010). The collapse was identified as an important signal contributing to a regime shift that occurred in the early 1990s (Buren et al. 2014, Pedersen et al. 2017). Several aspects of the stock’s dynamics, such as recruitment, growth, and mortality of pre-spawners have been linked to bottom-up processes (Frank & Leggett 1981, Leggett et al. 1984, Dalley et al. 2002, Buren et al. 2014, Obradovich et al. 2014, Murphy et al. 2018).

Frank et al. (2016) concluded that the capelin stock off Newfoundland and Labrador did not collapse. To reach this conclusion they analyzed several aspects of the biology of capelin (i.e. distribution and demography), some aspects of the surveys carried out by Fisheries and Oceans Canada, and the response of components of the ecosystem to the large scale changes that occurred during the early 1990s. These authors postulated that the reported collapse was not real and proposed two hypotheses to interpret why the surveys have failed to detect large fish aggregations; 1) capelin changed its migratory patterns while the timing of the survey has remained constant leading to a spatio-temporal mismatch between the survey and the stock, and 2) the capelin stock has become less migratory remaining in inshore waters, and therefore undetected by the offshore surveys.

The objective of this paper is to assess the relative empirical support for the hypotheses of stock collapse (DFO 2015) vs non-collapse (Frank et al. 2016).

ADB: Hannah, I am not happy with the last sentence, but I feel like I am running in circles. Can you have a crack at this, please? Thanks!

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