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The roles of fishing and environmental change in the decline of Northwest Atlantic groundfish populations in the early 1990s

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ABSTRACT

The cause of the large decline in groundfish populations in the Northwest Atlantic about 1990 remains unresolved although the prevailing view is that it was due predominantly to fishing. A similar but less extreme decline in these populations that occurred in the early 1970s is also attributed to fishing. However, observational data on commercial fishing effort suggest that fishing effort in the late 1980s was likely less than in the late 1960s–early 1970s, even when efficiency increases are accounted for. Also, the biological changes observed in groundfish populations in the late 1980s were not consistent with a hypothesis that the early 1990s declines in biomass were caused by recruitment overfishing. There is, however, a strong coincidence between fluctuations in groundfish biomass, and other biological characteristics, and variations in the North Atlantic Oscillation (NAO), suggesting that the rapid changes in these characteristics in the early 1990s were largely due to environmental variations, and that this equally may have been true for early 1970s population changes. A corollary to such a hypothesis is that the 1960s, when NAO anomalies were consistently and strongly negative, was a period uniquely favourable for groundfish productivity and should not be taken as a long-term norm.

1. Introduction

The Northwest (NW) Atlantic fisheries underwent a major expansion from the 1950s. The catches of groundfish (demersal fish) peaked in the late 1960s, reflecting a decline in abundance of groundfish populations that continued through the mid 1970s. Groundfish abundance increased in the late 1970s and early 1980s but this recovery was followed by a second, more severe, decline in the late 1980s and early 1990s that precipitated closures of fisheries for Atlantic cod (*Gadus morhua*) and other species in many management areas beginning in 1992.

This early 1990s event was not foreseen by the scientific community responsible for providing advice to fishery managers and the reason for the widespread fishery failures was a matter of conjecture. However, the initial analyses put forward in the primary literature supported fishing alone as its cause (Hutchings and Myers, 1994; Hutchings, 1996; Myers et al., 1996). More recent analyses have qualified this initial conclusion by recognizing that a coincident reduction in groundfish productivity indicated that there was an environmental contribution to the population declines (e.g. Rose et al., 2000; Parsons and Lear, 2001; Rice, 2002; Rothschild, 2007; Schrank, 2007). Nonetheless, it appears that the most generally accepted view among scientists conducting research on this issue remains, as expressed by Shelton et al. (2006), that "Excessive and unsustainable fishing mortality was the predominant factor in the depletion of NW Atlantic cod (*Gadus morhua*) stocks".

The decline in groundfish populations during the early 1970s was less severe than in the early 1990s but was equally widespread geographically. Of the three comprehensive reviews of this earlier event, the first, by Pinhorn and Halliday (1990), concluded that fishing provided a plausible explanation for the halving of groundfish abundance between 1967 and 1975 and their subsequent recovery, but could not rule out environmental factors as a cause. The two subsequent reviews (Sinclair and Murawski, 1997; Rice, 2002) concluded that this early 1970s event was due to fishing alone, and it appears that remains the prevailing view.

The present paper examines observational data on temporal trends in the amount of fishing effort, and changes in groundfish population parameters immediately prior to the early 1990s event, and finds that these cast doubt on the validity of the apparent consensus that fishing mortality was the predominant factor causing population declines (called here the 'fishing hypothesis'). The paper then examines the biological responses of these populations to changes in the North Atlantic Oscillation (NAO), used as an indicator of the environment, and makes a case for environmental change being the paramount cause of the early 1990s event. Extensions of this 'environmental hypothesis' to earlier events are

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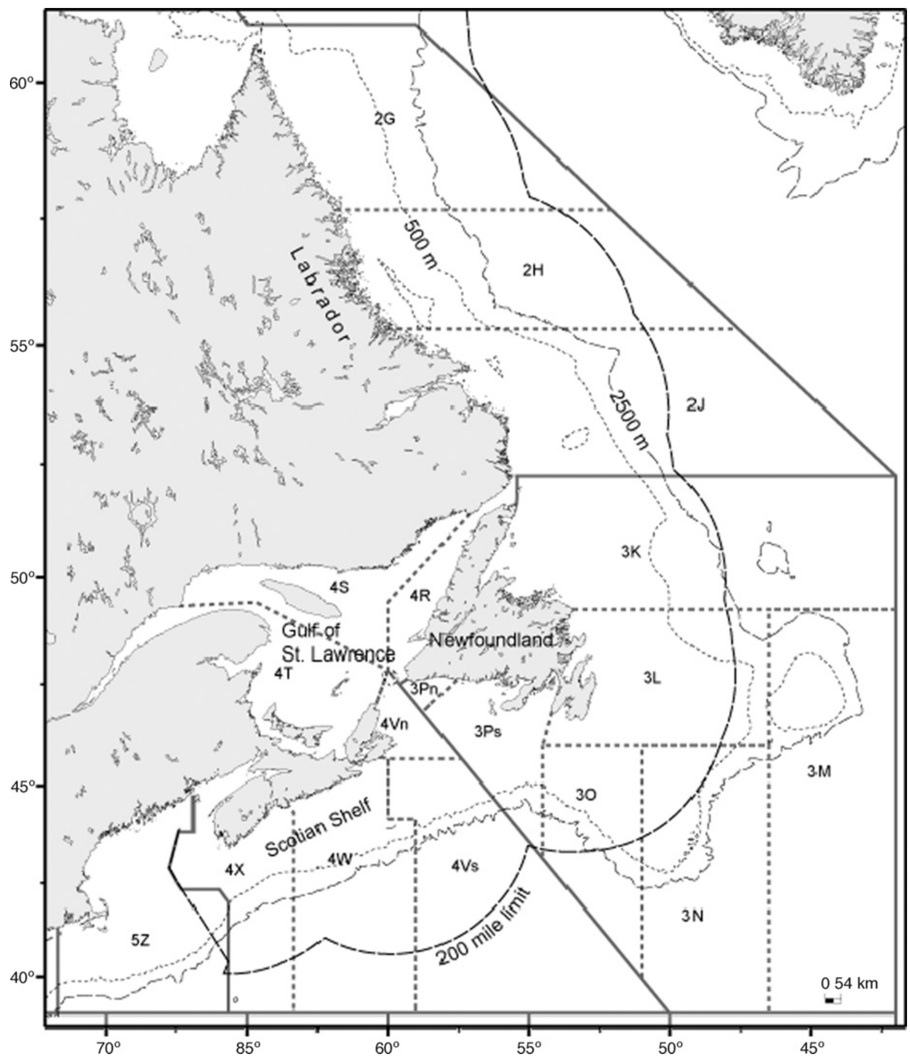

Fig. 1. Map of the NAFO divisions and subdivisions and the geographic locations mentioned in the text.

considered. Analyses are restricted to summarizations of original data and simple statistical tests, to minimize the number of assumptions that are made (i.e. no derivatives of Sequential Population Analyses (SPA) are used). All the changes in biological parameters have been addressed by previous authors, and are presented here primarily by literature review. However, the present analyses of the data for essentially all of the commercially important groundfish populations in Northwest Atlantic Fisheries Organization (NAFO) subareas (SA) 2–4 (Fig. 1), in relation to changes in the NAO, are novel.

This is also the first time that the observational data on the amount of fishing effort have been used to make inferences about fishing mortality (F) for groundfish as a whole in the NW Atlantic. Elements of the data have occasionally been used directly to make inferences about F for a single fish population, e.g. Hutchings and Myers (1994) and Hutchings and Ferguson (2000), but their primary use historically has been in the calculation of catch rates as abundance indices for use in calibrating (tuning) SPA models. This latter usage became less common as time series of fishery-independent indices became available from standardized research vessel (RV) surveys initiated in the 1970s (Doubleday, 1981).

Conceptually, F is proportional to effective fishing effort, f, i.e., $F = qf$ (where the proportionality constant, q, is referred to as the catchability coefficient). Before observed (nominal) fishing effort can be equated to effective fishing effort, it must be corrected for the effects of changes in fleet composition (vessel sizes and vessel/gear types) and for improvements in technology, e.g. in navigation and fish finding equipment, gear design and construction materials, i.e. to account for factors that could introduce a temporal trend in q. The NAFO database on catches and fishing effort contains data that allow for changes in fleet composition to be accounted for. This is not so for technological improvements, however, requiring that estimates from the literature be used to establish reasonable bounds for such improvements during the study period.

Although Mann and Drinkwater (1994) identified an association between the NAO index and the productivity of cod off southern Labrador and eastern Newfoundland in the early 1990s, it is only in more recent years that the importance of the NAO in determining hydrographic conditions and biological productivity throughout the North Atlantic has become widely recognized (Drinkwater et al., 2003). Drinkwater et al. (2003) point out that the NAO index has been found to account for as much and sometimes more of the variance in biological time series than local physical variables. Thus, variation in the NAO is used here as the basis for evaluating environmental effects on groundfish production in the NW Atlantic.

Reviews of biological changes are limited temporally by the availability of RV surveys, i.e. from about 1970 but later in some areas, and are restricted to cod, haddock (*Melanogrammus aeglefinus*), American plaice (*Hippoglossoides platessoides*), yellowtail flounder (*Limanda ferruginea*) and witch flounder (*Glyptocephalus