



Seal–cod interactions on the Eastern Scotian Shelf: Reconsideration of modelling assumptions

Robert O'Boyle^{a,*}, Michael Sinclair^b

^a Beta Scientific Consulting Inc., 1042 Shore Dr. Bedford, Nova Scotia, Canada B4A 2E5

^b Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2

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ABSTRACT

The cod stock on the Eastern Scotian Shelf (the 4VsW management area) collapsed in the early 1990s, and has experienced high natural mortality since then, while the abundance of grey seals foraging in the area has doubled about every seven years since the 1960s. The causes of the high cod natural mortality are not well understood, but seals are not considered to have played a significant role. This study takes a fresh look at the impact of seals on 4VsW cod abundance. Abundance trends of the Sable, Eastern Shore and Gulf seal herds which forage on the Scotian Shelf are estimated to 2020. The Sable herd is projected to stabilize at about 350,000 individuals. If their exponential growth continues, the Eastern Shore and Gulf herds could in aggregate reach about 200,000 individuals. However, density dependent processes are likely to slow population growth of these two herds sometime in the coming decade. Total annual food consumption of the three herds is estimated. In 2010, in excess of 550,000 t of fish are consumed annually by the Sable and Eastern herd, with the Gulf herd consuming about 138,000 t. The literature on seal diets is summarized and three scenarios of type II predator–prey functional response are defined. In an ADAPT analysis of the 4VsW cod stock, seals are treated as an additional fishing gear sector under two scenarios: respectively a “flat-top” and “domed” partial recruitment vectors. Model results infer that seals have contributed to increases in natural mortality since the late 1980s, and have contributed to the lack of recovery of the stock since 1993. However, predictions by the functional models are not consistent with estimate of recent increases in abundance of cod in trawl surveys. Present levels of grey seal abundance have not occurred on the Scotian Shelf since at least the 1800s.

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1. Introduction

Interpretation of the collapse of the cod stocks off Atlantic Canada, as well as their lack of recovery in spite of fishery closures and severe fisheries restrictions, continues to be controversial. The geographic and temporal patterns are complex, with the degree of the declines and their timing varying considerably amongst the cod management areas in the northwest Atlantic. This paper focuses on the impact of grey seals (*Halichoerus grypus*) on Atlantic cod (*Gadus morhua*) on the Eastern Scotian Shelf (4VsW management area) off Nova Scotia, Canada (Fig. 1).

Natural mortality of cod, and of several other fish species, in this geographic area has been exceptionally high in recent decades. As it is difficult to separate natural mortality from fishing mortality (particularly when there are directed fishing activities underway), the estimates of temporal and spatial patterns of cod natural mortality are approximate in nature. Halliday and Pinhorn (2009) provide a

review of changes in natural mortality for a number of fish species in the northwest Atlantic. They conclude that the increases preceded the fishery closures in 1992/1993. The 4VsW cod stock has continued to decline in spite of the closure of a directed fishery since 1993. Research surveys indicate that high levels of total mortality have continued, even after closure of the 4VsW cod fishery in 1993, implying that natural mortality has been exceptionally high during the past two decades. However, since 2006, there has been an increase in the survey trawl estimates of cod biomass and an associated decrease in the estimates of natural mortality (Fig. 2).

Coincident with the increase in natural mortality of cod (and other fish species), there has been an additional relatively unique marine ecological phenomenon. Grey seal pup production on Sable Island has been increasing by about 13% annually since the early 1960s (Bowen et al., 2003), while the Gulf of St. Lawrence component of the population complex has been increasing at 7.4% annually (Hammill et al., 1998). Grey seal abundance on Sable Island has been growing exponentially for four decades, doubling about every seven years, as has their annual food consumption. Exponential growth over several decades is rarely observed in the nature. The coincidence of these two observations – the dramatic changes

* Corresponding author.

E-mail address: betasci@eastlink.ca (R. O'Boyle).

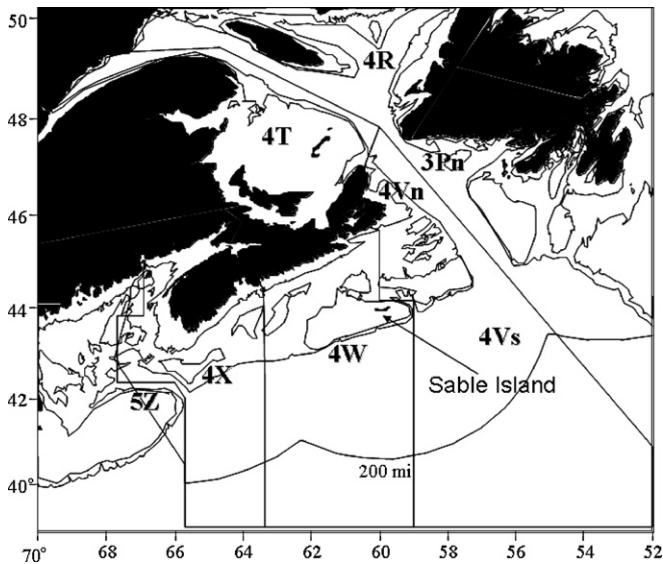


Fig. 1. Gulf of St. Lawrence (4T and 4Vn), Eastern Scotian Shelf (4Vs and 4W), Western Scotian Shelf (4X) and Georges Bank (5Z); Sable Island is indicated in 4W.

in natural mortality of cod and the exponential growth of a top predator (from about 3000 seals on Sable Island in 1960 to over 300,000 in recent years) – has generated speculation by the general public and fishing industry that the two phenomena may be connected. In particular, the fishing industry feels strongly that grey seals are responsible for the increases in natural mortality of cod (and other fish species of commercial importance). That said, they accept that overfishing had also occurred prior to the 1993 closure.

There have been several evaluations of the impact of grey seals on the cod stocks off Atlantic Canada. Mohn and Bowen (1996), based on a “minimum realistic” predator/prey model for the Eastern Scotian Shelf area (4VsW) for the 1970–1994 period, concluded that grey seals were not a major factor in the collapse of the stock. Sinclair et al. (1997), based on a comparative analysis of fisheries management practices on the Eastern (4VsW) and Western (4X) Scotian Shelf, concluded that a combination of poor environmental conditions and increases in natural mortality (in part due to seal predation) had contributed to the decline in stock production and recruitment. Fu et al. (2001) evaluated the causes of the lack of

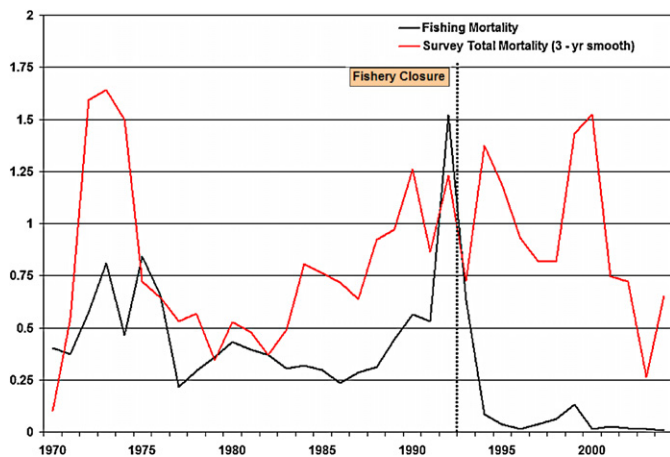


Fig. 2. Trends in adult fishing and total mortality of 4VsW cod during 1970–2005; the total mortality estimates (3-year smooth of age 5–7) are derived from the research vessel trawl survey catches; the closure of fishery in 1993 is indicated; after 1992, total mortality is an estimate of natural mortality.

recovery of cod on the Eastern Scotian Shelf following the 1993 fishery closure. They concluded that seal predation was not a significant factor. Trzcinski et al. (2006) also focused on the lack of recovery of cod since 1993. They concluded that grey seals had made some contribution to increases in cod rates of natural mortality (0.21 yr^{-1}) in the post fishery closure period, but that “unknown sources of mortality (0.62 yr^{-1}) are contributing to the failure of cod to recover”. Trzcinski et al. (2009) updated their model, and included an analysis of the Western Scotian Shelf (4X) management area. For both management areas, they conclude that seal predation on cod is a minor contribution to natural mortality. Again, other unknown sources are concluded as having caused the stocks to decline (in 4X where there is an ongoing fishery) and to not recover (in 4VsW which has been closed to cod fishing since 1993).

Bundy (2004), and Bundy and Fanning (2005), developed an Ecopath mass-balance model of the Eastern Scotian Shelf to compare the pre-collapse (1980–1985) and post-collapse (1995–2000) periods. The results indicated high predation mortality on both small (<40 cm) and large (>40 cm) cod (i.e. the Ecopath model confirmed the increases in natural mortality that had been estimated from the research vessel surveys and in other models). The sources of the high natural mortality for the large cod were unaccounted for, and Bundy (2004) concluded that their Ecopath model had not helped to explain this phenomenon. Furthermore, Bundy and Fanning (2005) concluded that grey seals cannot account for the high levels of “unaccounted for” natural mortality of cod estimated from the model. Bundy et al. (2010) expanded the Ecopath modelling through a comparative analysis of four geographic areas off Atlantic Canada (Newfoundland and Labrador Shelf, Northern Gulf of St. Lawrence, Southern Gulf of St. Lawrence, and the Eastern Scotian Shelf). Although they conclude that seal predation is a significant cause of the elevated natural mortality of cod for three of the areas, this was not considered to be the case for the Eastern Scotian Shelf management area. This is a paradoxical conclusion given that the rate of increase of grey seal abundance during the time period of the analysis is higher in the 4VsW management area than in 4TVn. Also, the other seal species of importance as predators in the northern Gulf and the Newfoundland and Labrador shelves (harp and hooded seals) have not been increasing at as high a rate as that for grey seals.

For the Southern Gulf of St. Lawrence, Chouinard et al. (2005) and Swain and Chouinard (2008), on the basis of correlations of trends in natural mortality of cod and abundance of grey seals, conclude that there is a tight correspondence. They note, however, the anomaly that high natural mortality is estimated for cod greater than age 3, whereas the diet of grey seals is estimated to comprise mostly juvenile cod (ages 1–3).

In summary, the scientific literature on the impacts of grey seals on the temporal trends in natural mortality and abundance of cod does not support the interpretations of the fishing industry on the observed dramatic ecosystem changes on the Scotian Shelf during the past three decades. To the degree that there is a scientific consensus, grey seals are not considered to have been a significant predator of cod on the Scotian Shelf. Grey seals are, however, considered to be a major contributor to the increase in natural mortality in the southern Gulf of St. Lawrence (Bundy et al., 2010; Chouinard et al., 2005; Swain and Chouinard, 2008). With the exception of Sinclair et al. (1997), no studies conclude that grey seals have contributed to the collapse of the cod stocks in this area during the late 1980s and early 1990s.

Given the contradictions amongst geographic areas in the interpretations of the role of grey seals on cod population trends, and the unexplained increase in natural mortality of cod on the Eastern Scotian Shelf since the late 1980s, this paper re-evaluates the impacts of grey seals on cod on the Eastern Scotian Shelf. The following aspects are addressed:

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