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# Demersal groundfish assemblages and depth-related trends on Flemish Cap (NAFO division 3M): 2004–2013

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ABSTRACT

We examine groundfish assemblage structure and diversity in relation to depth on the Flemish Cap using data from a multispecies bottom trawl survey performed by the EU. The data include 1699 hauls prosecuted between 129 and 1460 m and collected from 2004 to 2013. We focused on the 29 most abundant species, which made up 99.2% and 99.1% of the fish catch in terms of biomass and abundance respectively. Assemblage structure was strongly correlated with depth. We identified three main assemblages: assemblage I (Shallow, shelf, <250 m), assemblage II (Intermediate, upper-slope, 251–600 m) and assemblage III (Deep, medium-lower, >601 m). Despite dramatic changes in biomass and abundance of the species in the area, the boundaries and composition of the assemblages seem to be similar to the period before the collapse of Atlantic cod in 1998. The main differences between periods were replacements of the dominant species in several assemblages and bathymetric range extension of some species.



## 1. Introduction

Changes in ocean climate combined with direct and indirect effects of harvesting can dramatically and rapidly alter the composition of marine fish communities (Hutchings and Reynolds, 2004). The global crisis in overexploitation of fisheries has resulted in calls for multispecies or "ecosystem-based" assessment and management of fish stocks and assemblages (Jennings and Kaiser, 1998; Pauly et al., 2002; Worm et al., 2009). An ecosystem approach to fisheries management (EAFM) (ICES, 2000; FAO, 2001) in marine waters has long been advocated as a way to gain a better understanding of the structure and functioning of ecosystems and to eventually restore and sustain them (Tolimieri and Levin, 2006; Nogueira et al., 2015, 2016). A first step towards ecosystem management is to identify species assemblages and the biological and environmental conditions associated with these assemblages (Mahon and Smith, 1989; Gomes et al., 1992; Tolimieri and Levin, 2006) because this information helps us to understand which species likely interact and will be impacted similarly by management decisions. In recent decades numerous papers have described demersal fish assemblages: in tropical areas (Bianchi, 1991); in the Scotian Shelf and the Gulf of St Lawrence (Bundy, 2005); Norwegian Sea (Lekve et al., 1999); in the Mediterranean Sea (Moranta et al., 1998); in the NW Iberian Peninsula (Fariña et al., 1997); off the West coast of North America (Cope and Haltuch, 2012; Tolimieri and Levin, 2006); in the mid-Atlantic (Azores Archipelago) (Menezes et al., 2006).

With regards to Northwest Atlantic, some authors have conducted studies of assemblages in this area. Mahon and Smith (1989) identified similar assemblage structure on Scotian Shelf and in the Bay of Fundy from 1970 to 1981. Gomes et al. (1992) found six assemblages over 16 years (1971–82, 1984–87) on the Grand Banks of Newfoundland; Nogueira et al. (2013) found five assemblages in the South of the Grand Banks (Regulatory Area of NAFO [NRA] Divisions 3NO). Previous works on the Flemish Cap (NRA Div. 3M) found three main assemblages, in a heavily exploited period (Paz and Casas, 1996) and during the moratorium of main commercial shallow species (González-Troncoso et al., 2006). These two analyses were limited to a maximum depth range of 730 m.

The Flemish Cap Bank (NRA Division 3M, centred at 47°N 45°W) is part of the Labrador Newfoundland Large Marine Ecosystem (Fig. 1). It is an isolated bank separated from Newfoundland by 300 nautical miles and the Flemish Pass, a channel with depths greater than 1100 m (Stein, 1996; Templeman, 1976). The Flemish Cap is completely within international waters. It is an internationally used fishing ground most noted for Atlantic cod (*Gadus morhua*), but

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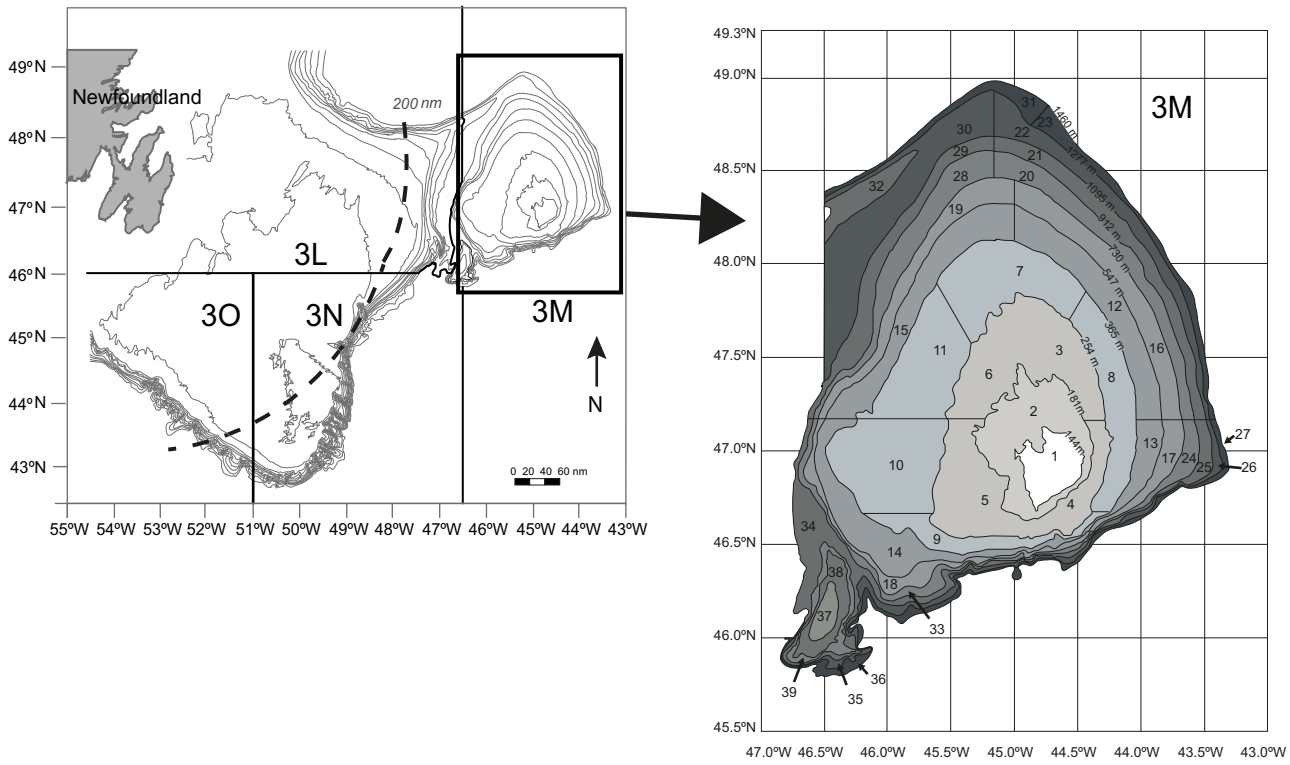


**Fig. 1.** Chart of the NAFO Divisions 3LMNO. EU bottom trawl area in Flemish Cap (NAFO Regulatory Area, Division 3M) is marked by the square.

haddock (*Melanogrammus aeglefinus*), redfish (*Sebastes spp.),* flatfish (including halibut), mackerel (*Scomber scombrus*) and herring (*Clupea harengus*) are also caught (Rose, 2003). The general circulation in the vicinity of the Flemish Cap consists of the offshore branch of the Labrador Current which flows through the Flemish Pass on the Grand Bank side and a jet that flows eastward north of the Cap and then southward east of the Cap. To the South, the Gulf Stream flows to the northeast to form the North Atlantic Current and influences waters around the southern areas of the Cap. In the absence of strong wind forcing, the circulation over the central Flemish Cap is dominated by a topographically induced anti-cyclonic (clockwise) gyre (Akenhead, 1986; Stein, 1996).

In 1977, with the establishment of Canada's 200-mile limit and declaration of its Exclusive Economic Zone (EEZ), fishing effort on this bank intensified as the international fishing fleet shifted effort out of the newly established Canadian EEZ to these international waters. In 1998, the collapse of cod stock led to the imposition of a moratorium (from 1999 to 2009) on fishing cod (Vázquez and Cerviño, 2005). The collapse has been attributed to three simultaneous circumstances: a stock decline due to years of overfishing, an increase in catchability at low abundance levels and a series of very poor recruitments starting in 1993 (González-Troncoso et al., 2013). Pérez-Rodríguez et al. (2012) identified overall the fishing pressure, environmental factors and predation pressure as main drivers to explain the temporal dynamics in Flemish Cap.

The collapse of other main commercial species also occurred in the Grand Banks of Newfoundland in 1991–92 and coincided with a period of extreme ocean conditions, including record cold temperature (Drinkwater, 2002). Both, overfishing (Hutchings and Myers, 1995) and oceanographic changes explains the Northern cod collapse (Sinclair and Murawski, 1997). Others potential hypotheses could have played a role in the collapse, included diseases and parasites, contaminants, starvation and/or poor condition, changes in life history and predation by marines mammals (summary in DFO 2009; Buren et al., 2014; Koen-Alonso et al., 2010). After the collapse of cod, fishing on the Flemish Cap has mainly focused on an increasing population of North Shrimp (*Pandalus borealis*) and Greenland halibut (*Reinhardtius hippoglossoides*) (Anon, 2002; Casas-Sánchez, 2010; Pérez-Rodríguez et al., 2012). Due to the decrease of Northern shrimp and the recovery of the cod in the last years, current fisheries are targeting cod at depths less than 300 m, redfish in depths less than 700 m and Greenland halibut in depths more than 700 m.

With the extension of deep-sea fisheries, there has been increased interest in the ecology of the resident species (Priede et al., 2010). EU (European Union) (Spain and Portugal) has performed a bottom trawl survey on Flemish Cap since 1988 (NRA Regulatory Area Division 3M) (Fig. 1).

In the present study, we used data from the EU bottom trawl survey from 2004 to 2013 to describe the assemblage structure of groundfish on Flemish Cap in relation to depth in order to expand upon previous studies (Paz and Casas, 1996; González-Troncoso et al., 2006) by extending the depth range of the analysis and by investigating potential temporal changes across fishing regimes. Specifically, we (i) extend the bathymetric range for the identification and description of fish assemblages (from 730 m to 1460 m maximum depth range); (ii) determine whether the species assemblages of demersal fish follow similar depth patterns through time; and (iii) ask whether there have been any changes in the dominant species in each assemblage with intensified fishing and recovery.

## 2. Material and methods

### 2.1. Study area

The Flemish Cap has a diameter at the 500 m isobath of about 200 km and a total area of approximately $3.0 \times 10^4$ km$^2$. To the West the Flemish Pass, with water depths of about 1100 m, separates the Flemish Cap from the Grand Banks of Newfoundland. The surveyed area outside Canadian EEZs covers almost the entire bank of Flemish