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Higher food abundance reduces the catchability of cod (*Gadus morhua*) to longlines on the Faroe Plateau

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ABSTRACT

The cod fishery at the Faroes has been managed since 1996 by an effort management system where it is assumed that there is a direct relationship between fishing mortality and fishing effort. We show that this relationship is weak. Due to a factor five variation in the primary production on the Faroe Plateau, the annual growth rate of cod may vary by a factor of five. Commercial catch-per-unit-effort data in combination with stock assessment estimates showed that there was a negative correlation between the annual growth rate of cod and their catchability with longlines, as well as with the total fishing mortality of cod on the Faroe Plateau. Furthermore, mark-recapture experiments showed that longline-caught cod in comparison with trawl-caught cod had a lower condition factor, a lower stomach content of natural prey, and a higher content of longline baits. During the feeding season in September–December, longline-caught cod exhibited a larger displacement distance than trawl-caught cod. These results were largely confirmed by storage tag data. Consequently, during low-productive periods, (i) the longline-dominated cod fishery at the Faroes exerted fishing mortalities that by far exceeded safe biological limits, and (ii) longline catch-per-unit-effort series might overestimate stock size considerably.

1. Introduction

The Faroe Plateau is located approximately mid-way between Iceland and Scotland (Fig. 1). Cold deep Norwegian sea water dominates the deep areas (>500 m) while warm Atlantic water is found at shallower depths. Residual currents have a persistent clockwise circulation around the islands (Gaard and Hansen, 2000; Hansen, 1992; Simonsen, 1999) which gives rise to a self-sustained plankton and fish community on the Faroe Plateau (see Steingrund and Gaard, 2005), including a self-sustained cod stock (Jákupsstovu and Reinert, 1994; Joensen et al., 2005; Steingrund and Gaard, 2005). The size of the Faroe Plateau cod stock has varied between 25 and 160 thousand tonnes during 1961–2006, being on average 88 thousand tonnes (ICES, 2007). The catch has varied between 6 and 40 thousand tonnes and the average fishing mortality (average of ages 3–7 years) between 0.19 and 0.82 (ICES, 2007).

The large annual fluctuations in the stock size have been attributed to the varying primary production on the Faroe Shelf (Gaard et al., 2002). There is a positive relationship between the primary production and the individual growth, recruitment and overall production of cod on the Faroe Plateau (Gaard et al., 2002; Steingrund and Gaard, 2005). The link to the primary production must imply that the variation in the primary production is reflected in the abundance of natural food organisms for cod. Cod prey mostly on sandeels (*Ammodytidae*), benthic crustaceans, small haddock *Melanogrammus aeglefinus*, Norway pout *Trisopterus esmarkii*, and blue whiting *Micromestistius poutassou* (Du Buit, 1982; Rae, 1967).

The fishing mortality seems to be negatively correlated with the primary production, and a negative relationship has been observed between individual growth and fishing mortality (ICES, 2007). Longliners take between 30 and 65% of the cod catch (ICES, 2007) – the longliners operate in the shallow areas with the largest cod concentrations – and the annual fluctuations in fishing mortality have been linked to a fluctuating catchability of longlines in several ICES working group reports (e.g., ICES, 2007) and in Steingrund et al. (2003).

An effort management system was introduced in 1996 after a 2-year period with a quota system (Jákupsstovu et al., 2007). The goal was to regulate the fishing effort by closed areas, number of fishing licenses, technical means (e.g., the size of fishing vessels), and the number of fishing days per vessel. It was assumed that there was a direct relationship between the number of fishing days and fishing mortality, i.e., that the catchability was constant between years.

The goal of this paper is to investigate whether the catchability is affected by natural factors such as food availability. This was investigated on a group basis by (i) comparing annual variations in longline catchability with annual growth rates of cod, and (ii) on an

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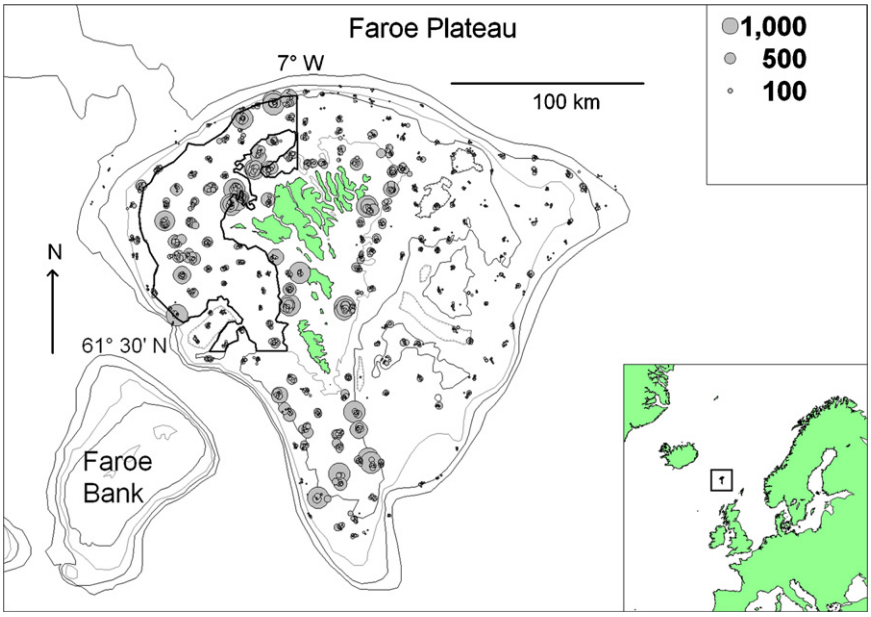

Fig. 1. The study area consisting of the Faroe Plateau and the Faroe Bank. The northwestern area on the Faroe Plateau, depths 100–200 m, was selected for the analysis of longline catchability. The catch rates of cod (kg/h) in the August groundfish trawl survey 1996–2006 are shown. The 100–500 m depth contours are shown.

individual basis by comparing characteristics (e.g., stomach content, displacement distance) of individual conventionally tagged cod that were recaptured by longline or by trawl. In addition, activity data from Data Storage Tags were related to cod condition and the recapture gear.

2. Materials and methods

2.1. Surveys and stock assessment of cod

An overview of the data and some procedures used in this manuscript is given in Table 1. The August Groundfish Survey CPUEs (kg/tow) were used to show the typical distribution of cod on the Faroe Plateau, including the area where the longliners operated. The August Survey has been conducted during August since 1996 (ICES, 2007). The Faroe Plateau is covered by 200 stations, which are occupied both day and night. The fishing gear is a 116 feet box trawl using doors of the Thyborøn type, and the length of the bridles is either 60 m (<~140 m depth) or 120 m (in deeper waters). The mesh size in the cod-end is 40 mm. The tow duration is 1 h and the towed distance approximately 3 nautical miles. The survey catch is assorted into fish species. When less than 200 individuals of a species are caught, normally all individuals are length-measured. Otherwise, the catch is subsampled for lengths, the rest catch is weighted, and the total catch per tow obtained.

A survey has also been conducted in March on Faroe Plateau since 1982, where 100 stations, all included in the August Survey, are occupied. In the stock assessment, the March Survey (data from 1994) and the August Survey are used to tune a virtual population analysis, which provides estimates of the absolute numbers-at-age (N) present in the cod population on the Faroe Plateau during the period 1961–2006 (ICES, 2007).

2.2. Logbook data for the longliners

No scientific longline data exist for the Faroe Plateau so data from the commercial longline fleets are the only source of information. Fishing vessels larger than 15 GRT are obliged to fill out

Table 1
Overview of the data and some of the procedures (in italics) used in this article. '*N*' is number-at-age from the stock assessment, and 'B' is the biomass (B3+ is for ages 3 and older).

Description of data/*procedure*	Section	Purpose	Time span	Data source
CPUE per tow for the August Survey	2.1	Spatial distribution, used to select area and depth	1996–2006	Original data
Stock assessment	2.1	Stock size (N and B)	1961–2006	ICES (2007)
Logbook data for five longliners	2.2, 2.3	Time series on CPUE (kg/1000 hooks) for three 4-month seasons (1,2,3)	1986–2006	Original data
Selection of the northwestern part of Faroe Plateau at 100–200 m depth	2.3	To standardize the area and depth	1986–2006	
Autumn–spring CPUE = Average of CPUE for season 3 and season 1 the following year	2.3	To reduce sampling error.	1986–2005	
Samples of lengths and ages of individual cod from commercial catch	2.4	Age-disaggregation of CPUE for seasons 1 and 3. Season 2 was omitted due to sparse sampling	1989–2006	Original data
CPUE/N by age	2.5	A measure of catchability	1989–2006	
Autumn–spring catchability = autumn–spring CPUE/B3+ in October	2.5	An average catchability, which is less prone to sampling error	1986–2005	
Weight-at-age data in the commercial catch	2.6	Change in weight is a measure of individual growth	1961–2006	ICES (2007)
Length–weight data in the August Survey	2.6	Fulton condition factor: a measure of individual growth	1996–2006	Original data
Conventional tagging data and corresponding stomach data	2.7	Obtain a relationship between feeding, migration, and the recapture gear (longline or trawl)	1997–2006	Original data
Storage tag data	2.7	Detailed fisheries-independent information on fish activity	1997–1999	Original data