Fisheries Research 181 (2016) 222–233

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

The response of the North Sea demersal fish community to changing fishing pressure as seen through the prism of the large fish indicator

Antonios Stamoulis[a,b,*], Els Torreele[a]

[a] Institute for Agricultural and Fisheries Research (ILVO Fisheries), Ankerstraat 1, Oostende 8400, Belgium
[b] Aquaculture and Fisheries Group, Wageningen University and Research Centre, PO Box 338, 6700 AH Wageningen, Netherlands

ARTICLE INFO

Article history:
Received 14 October 2015
Received in revised form 19 April 2016
Accepted 20 April 2016
Handled by George A. Rose
Available online 19 May 2016

Keywords:
Demersal fish community
Large fish indicator (LFI)
North Sea
Good environmental status (GES)
Size-based indicators

ABSTRACT

The large fish indicator (LFI) is a size-based indicator of fish community state. In the North Sea, the LFI is already established as the fish community's Ecological Quality Objective (OSPAR-EcoQO). The LFI has also been proposed as an indicator for food webs and for monitoring of biodiversity in European regional seas. The LFI was developed based on the entire North Sea fish community, which ignores the differences between the southern and the northern fish communities from the International Bottom Trawl Survey (IBTS) data. In this study, we have calculated LFIs based on IBTS and the Beam Trawl Survey (BTS), which target different components of the fish community and we test whether the LFI responds to changes in fishing pressure. The results did not confirm our expectation of a negative correlation between the pressure and state. We found a positive relationship between the IBTS-based LFI and the roundfish fishing mortality as well as an inverse relationship between the BTS-based LFI and the flatfish fishing mortality. The differences in the relationships between the IBTS- and BTS-based LFI and the respective roundfish-averaged and flatfish-averaged fishing mortality confirmed the spatial differences between the North Sea roundfish and flatfish fish communities. Although previous relationships between the LFI and the fishing pressure involved lengthy time-lags (10–12 years), we found shorter responsiveness of the LFI of 1–2 years. Further understanding of the ecological, environmental and anthropogenic factors affecting the LFI is required before ecosystem objectives can be set within the MSFD.

1. Introduction

Fish size is a central factor to key ecological processes. Almost all fisheries select large fish for economic reasons (Law, 2000; Sampson, 2014; Zimmermann and Heino, 2013). Size-selective fishing may lead to significant modifications in the size composition of exploited communities (i.e. smaller mean body size), which in turn affects the structure and function of the fish communities (Beverton and Holt, 1993; Jennings et al., 1999a,b). On population level, size structure represents diversity amongst individuals and can be therefore seen as a facet of biodiversity (Kenchington and Kenchington, 2013). Furthermore, because removal of large fish diminishes the predation pressure on their (smaller) prey and thus reduces their natural mortality, it is also received as a top-down pressure through the trophic levels (Beverton and Holt, 1993; Jennings et al., 1999a,b; Pauly et al., 1998; Rice and Gislason, 1996). As such, fisheries scientists and managers with interest in overfishing gave a lot of attention to overfishing of larger species in a fish community.

Size-based indicators (SBIs) are used to demonstrate the effects of fishing on the structure of the fish community (Rombouts et al., 2013; Shin et al., 2005). The Large Fish Indicator (LFI) is an SBI that identifies changes in the size composition of the fish community. The LFI calculates the proportion of fish above a specified length threshold based on either biomass or length. This calculation is meant to quantify the negative effects of human activities on the state of the North Sea's demersal fish community (Greenstreet et al., 2011).

In recent years the LFI has gained in importance and popularity at the marine policy level. It was adopted by the OSPAR commission (Oslo-Paris convention for the protection of the marine environment of the north east Atlantic) as the fish community Ecological Quality Objective (EcoQO) in the greater North Sea (Greenstreet et al., 2011; Heslenfeld and Enserink, 2008) and proposed as a food-web indicator to support the assessment of Good Environmental Status (GES) in the European Marine Strategy Framework Directive (MSFD) under Descriptor 4 (food web D4-marine food web

* Corresponding author at: Institute for Agricultural and Fisheries Research (ILVO Fisheries), Ankerstraat 1, Oostende 8400, Belgium.
E-mail address: antonios.stamoulis@gmail.com (A. Stamoulis).

http://dx.doi.org/10.1016/j.fishres.2016.05.002

indicator 4.2.1) (ICES, 2015). In a strict fisheries management context, the LFI has been selected as 1 of the 3 state indicators within the Data Collection Framework of the European Union (DCF2-LFI) (EC, 2008; ICES, 2013a), and Member States are required to collect data for calculating the LFI.

The basic principle behind the LFI is that a reduction in fish harvesting would lead to a reduction in the fishing mortality, allowing more fish to live and live longer, having more time to grow towards their species-specific $L_{infinity}$ (the asymptotic length at which growth is zero). Greenstreet et al. (2010) developed a protocol for calculating the North Sea's LFI as the proportion of biomass of demersal fish larger than the length threshold of 40 cm. In their protocol, the indicator is based on fishery-independent data collected from the International Bottom Trawl Survey (IBTS) with an otter trawl used as standard gear (ICES, 2012). Greenstreet et al. (2010) assessed the relationship between the averaged fishing mortality (pressure) of a range of commercially exploited species (cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, saithe *Pollachius virens*, whiting *Merlangius merlangus*, plaice *Pleuronectes platessa*, sole *Solea solea* and Norway pout *Trisopterus esmarkii*) and the North Sea-averaged LFI (state) and found that the North Sea's LFI responds to changes in fishing mortality rates with a temporal lag of more than 12 years. But different areas of the North Sea host different communities: the southern part of the North Sea is dominated by flatfish whereas the northern part is dominated by roundfish (Daan et al., 2005, 1990; Fraser et al., 2008). This spatial variability in fish communities is also reflected in the fishing gears applied. Beam trawlers targeting primarily flatfish, are the most common gears in the southern North Sea, whilst otter trawlers targeting roundfish are found primarily in the northern North Sea (Jennings et al., 1999a,b). The gear used by the IBTS-based LFI developed by Greenstreet et al. (2010) therefore focuses mostly on the demersal roundfish fish community. This raises the question whether the pressure indicator used by the authors best reflects the aforementioned differences in the North Sea demersal community's structure. Knowledge of the regional differences in fish communities enables us to calculate the (averaged) indicator for different regional areas and to reconsider the large fish threshold at which the LFI most effectively responds to fishing pressure (Shephard et al., 2011). The IBTS is a recruitment survey for a variety of commercial (roundfish) species. In the contrary, the BTS was designed to be a coastal survey of the exploited components of the flatfish community and sole in particular. These surveys started with the primary aim of generating information about commercially important species (Daan et al., 2005). As all gears are species- and size-selective, surveys subsequently have a gear-biased view of the fish communities they sample (Greenstreet and Rogers, 2006). Therefore, an examination of different surveys should provide an interesting overview of LFI responses to different gears and sampling period. The recent decline in North Sea's fishing mortality and effort, along with the plethora of available fisheries independent survey data provide a firm ground to investigate how this SBI state indicator responds to changes in fishing pressure.

In the current study we have investigated whether the LFI reflects the changes of the fishing pressure on the North Sea's roundfish and flatfish communities. For the roundfish community, we calculated the LFI based on IBTS data in the greater, northern and southern North Sea. For the flatfish community in the southern North Sea, we used data from North Sea's Beam Trawl Survey (BTS), which is designed to estimate abundance of plaice and sole. As indicators of fishing pressure we used a) the annual fishing mortality rates (F) of the North Sea's flatfish and roundfish fish communities and b) the annual fishing effort of the beam and otter trawl gears in the North Sea. We assessed the pressure-state relationships (PS) between the fishing communities' mortality rates, effort and LFI. Additionally, we investigated the responsiveness and sensitivity of the PS relationships (when statistically significant). We contrast our results with the expectations raised by previous studies and consider the usefulness of calculating the indicator using alternative surveys.

2. Materials and methods

As an alternative to the commonly used North Sea LFI, this study combines (i) trends of the IBTS-based LFI and BTS-based LFI, (ii) the community's fishing mortalities for roundfish and flatfish species and iii) international fishing effort data of beam- and otter trawling in the North Sea.

2.1. Survey data

We used 2 survey datasets, the (NS-)IBTS and the BTS, which both focus on different areas of the North Sea. The IBTS samples the entire North Sea as well as parts of the Skagerrak and the Kattegak within the 200 m isopleth during the first quarter (Q1), using a Grand Overture Vertical (GOV) gear (Piet and Jennings, 2005; ICES, 2012), along with the High Opening Bottom Trawl (HOB) gear. Hauls carried out with the latter gear were excluded for standardisation purposes. The BTS, carried out in the 3rd quarter of every year (Q3) is more focused in the southern coastal areas of the North Sea. The BTS uses an 8 m beam trawl. In both surveys, all fish are identified and counted and most or all are measured. GOV gear targets primarily demersal roundfish species, whilst the beam trawl targets mainly flatfish. Detailed methods of fish handling, sampling and recording during the surveys of each country are described in the ICES trawl survey's website and survey manuals (ICES, 2014, 2013b, 2012).

The data were extracted from the ICES DATRAS online database of trawl surveys (http://www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx). We used raw "Exchange data" datasets downloaded on the 2nd of October 2013, ranging from 1985 to 2013 for the IBTS and during the period 1987–2012 for the BTS. Data analysis was performed using R statistical software (R Core Team, 2013) and the DatrasR package developed by D. Beare.

2.2. LFI calculation

The LFI captures changes that occur in the large fish community in relation to the small fish community (and vice-versa). The indicator thus depends on the ratio between the large and the small fish component as these are set above and below the threshold applied. The proportion of these 2 components can therefore be influenced by factors regulating two actions: i) the flow of fish into and out of the community and ii) the unidirectional inter-component flow of the fish that grow longer than the length threshold. Primary factors are the natural (including predation) and fishing mortality rates, as well as recruitment and growth. These factors are the main regulators of the total biomass in the system. However, processes do not only add or remove fish from the 2 components; other factors such as recruitment, growth, water temperature and availability of food either advance or deter the unidirectional movement of fish from one component to the other.

We calculated the LFI as the proportion of demersal fish by weight above a certain length threshold, as proposed by Greenstreet et al. (2010).

$$LFI, y = \frac{W_{>thr,y}}{W_{total,y}}$$

where y is a year, thr is the length threshold and w the biomass of individuals.