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Discarding of plaice (*Pleuronectes platessa*) in the Danish North Sea trawl fishery

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ABSTRACT

Plaice (*Pleuronectes platessa*) plays an important role in the North Sea benthic ecosystem and is by weight the most important commercial flatfish species in the North Sea demersal fishery. There is a high discarding of plaice in the active demersal fisheries in the North Sea. The change in fisheries management towards a more ecosystem based approach, together with a greater focus on sustainability, has caused a severe need for action. Subsequently, the European Commission is preparing regulations to reduce or even ban discards. The trawl fisheries are commercially the most important Danish fishery targeting plaice. Here we analyse discard data collected onboard Danish vessels in the period from 1998 to 2008. We describe the general patterns in these data by dividing them into three mesh size categories: 80–99 mm, 100–119 mm and ≥120 mm to reflect implemented technical measures of relevance. We analyse the landed and discarded portions in these mesh size categories and link the discarding to the minimum landing size. We employed a GAM model to assess how discarding of plaice below the minimum landing size is connected to relevant factors that could be of relevance from a management perspective. We identified a statistical significant effect of mesh size category and area. We discuss the results in relation to potential mitigation measures to be implemented in future fisheries management strategies.

1. Introduction

Plaice plays an important role in the North Sea benthic ecosystem, being one of the most abundant flatfish species and one of the most important species for the fishery (Daan et al., 1990; ICES, 2008; Sparholt, 1990). Nevertheless, the plaice fishery in the North Sea is characterized by a high discard rate, approximately 50% by weight of the catches (ICES, 2011). High mortality of discarded plaice (50–100%) is indicated from both beam trawls (Kaiser and Spencer, 1995; Van Beek et al., 1990) and trawls (Evans et al., 1994; Millner et al., 1993). Discard survival will likely depend on several factors like the fishing gear, fish and fishing conditions and an additional mortality caused by sea bird predation (Evans et al., 1994; Garthe and Hüppop, 1994; Hudson and Furness, 1988; Votier et al., 2004). Consequently, measures to reduce the amount of plaice discarded in the North Sea fisheries would greatly benefit the stock (ICES, 2011) and reduce the anthropogenic impact on the marine ecosystem. The reduction of discards is also a main issue in the 2012 revision of the European Common Fisheries Policy and a key aspect in voluntary certification of fisheries (Marine Stewardship Council, www.msc.org).

Several technical measures have been applied in the North Sea to reduce the fishing mortality on juvenile plaice. Of relevance for active demersal gears are mesh size regulations, a partially closed area (the plaice box) and a minimum landing size. The closed area (plaice box) is placed along the continental coast where vessels lager than 300 HP have not been allowed to fish since 1995 in an attempt to reduce discards of juvenile plaice (Pastoors et al., 2000; Van Keeken et al., 2007) that are concentrated in this area (Pastoors et al., 2000; Rijnsdorp and Pastoors, 1995; Van Keeken et al., 2007). There has not been proven any clear effect on the stock (ICES, 2011; Pastoors et al., 2000) but it is likely that this will increase survival of juvenile plaice. There are several mesh size regulations in force, and today the use of meshes 80–99 mm is only allowed in the southern North Sea (South of 55°N or 56°N east of 5°E) whereas the minimum mesh size in the North is 100 mm (ICES, 2011). Recent estimates on the selectivity of plaice in trawls have been made (Frandsen et al., 2009; Frandsen et al., 2010; Frandsen et al., 2011) making it possible to assess the selectivity in relation to discard mitigation measures.

Discarding of plaice is recognized as a major management problem and several aspects of plaice discarding in the North Sea have been assessed (Aarts and Poos, 2009; Berghahn and Purps, 1998; Depestele et al., 2011; Dickey-Collas et al., 2007; Evans et al., 1994; Poos et al., 2010; Van Beek et al., 1990). There is, nevertheless, a lack of publications that analyse and describe the general discard pattern of plaice in the North Sea trawl fishery with focus on potential mitigation measures. A particular reason is that discard sampling programmes are often expensive and require a large number of man hours, while providing data which are spare in relation to the total effort in a given fishery (Aarts and Poos, 2009; Dickey-Collas et al., 2007). However, discard

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analyses are of importance for inclusion in stock assessment and the associated management advice (Dickey-Collas et al., 2007).

Several technical measures have been implemented over the years, however, the level of discarding remains high (ICES, 2011). Therefore, evaluating factors that can be used by managers to reduce discard amounts and rates is of importance. Discard reduction is also an important facet of the long term management plan implemented in 2008, aiming at having the stock within safe biological limits (ICES, 2010). Trawls are the most important fishing gear targeting plaice in the Danish North Sea fishery. Discard data from the Danish fishery have been collected since the nineties. This provides the possibility to assess discarding for a relatively large number of hauls. Here we analyse discard data collected from the Danish demersal trawl fishery in the North Sea in the period from 1998 to 2008. The main aim is to analyse the discard data with particular focus on factors that could be important for management strategies in the future.

2. Methodology

2.1. Discard sampling

Danish discard data was originally collected under a national programme and later (2002) in accordance with the European Data Directive (1639/2001). Data sampling is stratified with regard to: ICES sub-division, quarter, and defined by mesh size categories. Sampling is carried out on board commercial vessels voluntarily participating in the discard sampling programme. The observer has no relation to the control units, whereby it is assumed that the fishing practice is unaffected by his presence. The vessels and trips are chosen to be representative of all important fishing harbours, the entire period, all vessel sizes and all durations of trips in the given fishery. The criteria for hauls included in this analysis are that they are conducted in the North Sea with demersal trawls in the period from 1998 to 2008 with a mesh size of 80 mm or larger. The trawls are fished in single or multiple rigs often from a single vessel, but in a few cases pair trawling is recorded (trawls towed by two vessels). These fisheries are generally defined by being mixed fisheries targeting species for human consumption. The fishery is complex, having fluctuating catch compositions and targeting a wide range of species.

2.2. Relevant factors

Many social (Catchpole et al., 2005; Rochet and Trenkel, 2005), technical (Rochet and Trenkel, 2005; Stratoudakis et al., 2001) as well as environmental (Catchpole et al., 2005; Rochet and Trenkel, 2005) factors can be considered as having a potential effect on discards. However, this analysis is focussed on variables that are relevant for management of the fishery because they are directly controllable. Factors considered include geographical area, season (quarter) and mesh size category (defined by mesh size intervals). The discard rate could be largely positively correlated with juvenile abundance. Although this is not controllable by managers it has the potential to distort the effect of other influential factors such as mesh size and was therefore also considered. We considered the size spectrum from the minimum retention length up to the MLS by using recruitment data for age classes one and two from the official assessment (ICES, 2010). We assessed juvenile abundance by year and quarter, assuming mortality (natural and fishing mortality) to be constant throughout the year. Year classes one and two were assessed separately and also their effects combined.

We defined haul location as the midpoint in the tows (straight line between start and end). To increase the number of observations for each time period we used quarter (start 1st January) rather than month. Since mesh size will influence the selectivity in the gears, it is considered to be a main factor affecting the discarding of plaice (ICES, 2011; Van Keeken et al., 2007). We divided mesh size into three main categories: 80–99 mm; 100–119 mm and ≥120 mm (largest observed size is 127 mm), reflecting the regulations. These include minimum mesh sizes of 80 mm in the southern North Sea, 100 mm in the northern North Sea and 120 mm for the whitefish fishery in the northern North Sea. This division also ensures a reasonable number of observations per mesh size category. The conventional mesh size is noted by the discard observers but is not necessarily measured. Since mesh size regulations have changed over the years, some of the discard observations are not in line with current legislation, having smaller mesh sizes than allowed in the area today. The mesh sizes are reported to be somewhat larger (around 5 mm) than the minimum allowed. This is to avoid potential conflict with the legislation, since the size of the mesh can decrease over time. It is rarely that the conventional mesh size is below the minimum allowed. The use of selective devices is not well documented in the discard data. However, square mesh panels have been implemented in legislation in some fisheries during the study period. These panels are inserted with the objective of improving the selectivity of gadoids, particularly cod, and do not fit well to the morphology of plaice. Subsequently, they are not expected to influence the selectivity of plaice (Frandsen et al., 2010; Madsen et al., 2006) since the minimum allowed mesh sizes in the square mesh panels are not substantially higher than that used in the rest of the codend. A minimum landing size (MLS) of 27 cm is effective for the whole investigated period.

Since a mismatch between mesh size and MLS is likely to be influential on discard rates we used recently published data on plaice selectivity in trawls (Frandsen et al., 2009, 2010, 2011) to assess this relationship further. We estimated mean values from 4 experiments assuming the selection factor (L50 (50% retention length)/mesh size) and also the selection ratio (selection range (75% retention length − 25% retention length)/L50) to be constant. This is because the selection range can increase with L50 and hence mesh size (Madsen, 2007). The average selection factor was estimated to 2.15 (range 2.04–2.28) and the average selection ratio to 0.146 (range 0.108–0.182).

2.3. Comparisons of mean values

Mean values for each mesh size category were estimated for discards and landings (no./hour), discard proportions (no.) and lengths (cm) of discards and landings. To conduct a more detailed analysis of discarding mean values in relation to MLS the total proportion below MLS, two length intervals just below MLS (23–24 cm and 25–26 cm) and a length interval just above MLS (27–28 cm) were estimated. All mean values were compared pair-wise by a two-sample *t*-test. In principle, this requires that the mean values approximately follow normal distributions. The observations are not normally distributed particularly because most cases include zero discard observations. However, the positive observations exceed the zeros in most cases. It was examined by bootstrap if the mean values approximately follow a normal distribution. This was done for each set of observations as follows: 1) draw a random sample of the observations with replacement; 2) calculate the mean; repeat steps 1 and 2 10,000 times; draw a histogram and a qq plot of the 10,000 simulated means. The plots indicate that the normal approximations seem reasonable. The applicability of the *t*-test is further justified by Sullivan and D'Agostino (1992), even in cases with up to 50% zero observations.

2.4. Modelling discarded numbers under MLS

To describe the main reasons for discarding that are relevant to management we modelled discarded numbers under MLS per haul as the response variable. However, as haul durations differ per observation we may simply measure a large number of discards because the haul duration was long. To account for this we used log haul duration as an offset term, whereby the fitted values are always positive,