Fisheries Research 147 (2013) 320–326

Contents lists available at ScienceDirect

Fisheries Research

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

Mortality of adult plaice, *Pleuronectes platessa* and sole, *Solea solea* discarded from English Channel beam trawlers

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ARTICLE INFO

Article history:
Received 24 August 2012
Received in revised form 24 June 2013
Accepted 8 July 2013

Keywords:
Beam trawling
Discard mortality
Plaice
Sole
Unaccounted fishing mortality

ABSTRACT

Owing to quota breaches, adult plaice, *Pleuronectes platessa* and sole, *Solea solea* are frequently discarded (with unknown fates) from beam trawlers working in the western English Channel. This study aimed to quantify the immediate and short-term mortalities of such discards, with a view towards prioritising mitigation strategies. During 121 deployments (hauls) by two beam trawlers alternately fishing across five consecutive months (starting January 2012), 1013 plaice (23–62 cm total length; TL) and 810 sole (23–52 cm TL) were assessed for immediate mortalities, while 120 and 90 alive individuals were subsequently monitored (along with 39 controls) in a purpose-built, on-board aquaria for three days. Immediate discard mortalities were similar among all months for sole (2.3–7.0%) and most months for plaice (1.2–6.8%), excluding February (26.2%) when individuals were in poor condition due to spawning. Of the plaice and sole monitored in the on-board aquaria, 62.5 and 56.7% died. For both species, immediate and short-term always decreased with increasing TL, and this relationship was statistically significant for the immediate mortality of plaice in February, and for their short-term mortality in the other months. The monthly ranges of mean total un-partitioned mortalities (±se) (accounting for control fatalities of 23.1%) were 20.4 ± 10.2 and 62.7 ± 7.3% for plaice, and 23.6 ± 10.2 and 46.9 ± 8.9% for sole. The results support avoiding targeting spawning fish and/or only discarding larger specimens as a means for reducing unaccounted fishing mortality due to quota restrictions.

1. Introduction

The western English Channel (contained within ICES subarea VIIe) supports several diverse commercial fisheries (Araújo et al., 2008); important among which is a beam-trawl fleet targeting more than 30 species of cephalopods and teleosts, but especially plaice, *Pleuronectes platessa* and sole, *Solea solea* (Enever et al., 2007). The current fleet comprises 47 vessels (20–30 m and up to 900 kW) operating from Plymouth, Brixham and Newlyn, and harvesting an estimated 15,000 t pa (source: UK Fisheries Authorities).

Like for all other English Channel fisheries, beam trawlers historically have been managed by stringent and often complex regulations designed to control exploitation. Currently, those vessels with a main engine output >221 kW (most of the fleet) are limited to waters >12 nm from the coast, and all have temporal restrictions on fishing within ICES subarea VIIe (e.g. in 2011, vessels were permitted a total of 5698 days or 2,432,598 kW-days of fishing). The vessels tow paired trawls fixed to rigid beams ≤12 m with a minimum mesh size of 80 mm (inside stretched mesh opening–SMO) in the codend. However, to minimise catching plaice and sole smaller than their minimal legal sizes (MLS) of 27 and 24 cm total length (TL), respectively most operators voluntarily use 90–100 mm mesh in codends, and much larger mesh in the trawl bodies; measures that have been deemed quite effective (Nelson and Revill, 2011).

Beyond the above input controls, both plaice and sole are also managed using total allowable catches that are dictated by the European Union (e.g. 777 t for sole caught in ICES area VIIe, and 5062 t for plaice caught in ICES area VIId,e during 2012). While this mechanism aims to prevent operators targeting plaice and sole once quotas are reached, it is based entirely on the catches landed at port. Consequently, because other important species occur across the same habitats in similar space and time as plaice and sole, and there are few operational or technical options for controlling species selection, at times large quantities of both species are discarded at sea, and across the range of adult sizes (i.e. ~25–65 TL; Enever et al., 2007).

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0165-7836/$ – see front matter.
http://dx.doi.org/10.1016/j.fishres.2013.07.005

Within Europe, there is strong political, public and industry support to eradicate (or at least minimise) discarding; a practice considered a major shortcoming of the Common Fisheries Policy and difficult to socially justify (Anon, 2008). Recently, the European Commission agreed to promote a programme of eradicating the discarding of many species (including plaice and sole) by 2018 (Anon, 2012). However, biological justification for such an outcome relies on unacceptable associated mortalities; the extent of which currently remains unknown for plaice and sole discarded by western English Channel beam trawlers.

Previous studies have shown that the fate of organisms discarded from towed fishing gears varies considerably among and within species, reflecting complex and often interacting fishery-specific biological, technical and environmental factors (reviewed by Davis, 2002; Suuronen, 2005; Broadhurst et al., 2006). The available data for plaice and sole support this trend with immediate or short-term (<7 days) discard mortalities from other North Sea fish and shrimp beam- and otter-trawl fisheries estimated at between 0 and 100% (Fulton, 1890; Borley, 1909; Kelle, 1976; van Beek et al., 1990; Berghahn et al., 1992; Fonds, 1994; Kaiser and Spencer, 1995). While there have been species-specific differences in mortalities (e.g. fatalities among plaice have been greater than for sole) and causes within studies, key (positively associated) factors have included the size of trawls (Fonds, 1994) and their tow duration (Borley, 1909; Kelle, 1976; van Beek et al., 1990; Fonds, 1994) and speed (van Beek et al., 1990), water temperature (van Beek et al., 1990), air exposure (Borley, 1909) and handling time (Kelle, 1976). Further, in many cases, for both species there has been a negative association between TL and either their immediate (Borley, 1909) or short-term mortalities (Kelle, 1976; Berghahn et al., 1992).

Although the above studies have provided important information on the fate of beam trawled-and-discarded plaice and sole across various conditions, a common limitation is that nearly all (but see Fulton, 1890) have been restricted to assessing juveniles (e.g. ~5–28 cm TL). Virtually no quantitative data are available describing discard mortality among adult conspecifics of either species. This shortfall, combined with clear fishery-specific variabilities among the discard mortalities of the studied small plaice and sole, makes it difficult to predict the fate of adults discarded owing to quota breaches by beam trawlers working in the western English Channel.

Given the above, the main aim of this study was to provide the first broad assessment of the partitioned (immediate and short-term) mortality of adult plaice and sole discarded during conventional beam trawling. A secondary aim was to identify potentially deleterious factors, with a view towards prioritising mitigation strategies.

2. Methods

2.1. Equipment used

The study was undertaken between January and June 2012 using commercial trawlers in the western English Channel. Prior to trawling, a portable fish-monitoring system was constructed so that it could be secured to the deck of each vessel (similar in concept to those described by van Beek et al., 1990; Kaiser and Spencer, 1995). The system comprised 20 rectangular polyvinyl chloride (PVC) containers (600 mm × 200 mm × 180 mm, but filled to 33 L), each fitted with 25-mm diameter (ø) PVC inflow and outflow pipes. All containers were covered, stacked in groups of four, and supplied pumped flow-through water (from the sea surface) at $13 \pm 5\,L\,min^{-1}$.

Discards were assessed during five, eight-day trips, alternately completed in consecutive months using two offshore vessels: the "Barentszee" —30 m long, 880 kW engine and towing paired 12-m beam trawls with 180-mm knotted polyethylene (PE) mesh in the body and the "Angel Emiel" —24 m, 224 kW, and rigged with two 9-m beam trawls made from 150-mm knotted PE mesh (Table 1). All trawl codends were made from 95-mm knotted polyethylene mesh.

2.2. Fishing protocol and data collected

At the start of each trip, the fish-monitoring system was secured to the trawler deck, and temperature loggers (Stowaway TidbiT TBI32 −20 + 50) were attached to the headline of one beam trawl and in one of the containers in the fish-monitoring system. The skippers were then asked to trawl as per commercial operations, including their preferred spatial and temporal deployments, with all relevant technical and environmental data (e.g. day, haul number, deployment time, trawling depth, speed and duration, and water temperature) subsequently recorded, along with the general weather conditions.

After each deployment, the codends were retrieved and emptied into a conveyor-belt rigged deck hopper (sprayed with seawater) for sorting by the crew. Data were collected on the total catch of fish and the estimated quantity of rock, debris and benthic invertebrates (using baskets of ~44 L). Both sole and plaice were immediately examined by an on-board scientist. Each fish's caudal peduncle was gently squeezed between finger and thumb and based on any perceived movement of their body and or operculum immediately classified as dead or alive (i.e. immediate mortality) before being measured (TL to the nearest 1 cm). During the second, third and fifth trips, up to 50 live individuals of each species were also 'discarded' (in pairs) into the containers in the fish-monitoring system (all within 10 min of landing) and monitored daily for three days (short-term mortality), after which survivors were released and additional fish were collected and monitored from subsequent deployments (Table 1).

Prior to the third trip (in March 2012), ~50 plaice and four sole were collected from a small otter trawler working inshore in depths of 40–50 m. Immediately after the codends were retrieved, catches were placed into large water-filled containers and live individuals transferred to the fish-monitoring system (all within 5 min). At the end of the fishing day, the fish-monitoring system was relocated to shore and supplied with fresh seawater as above for monitoring over three days. There were very few associated fatalities. Specifically, one sole and two plaice died during transfer to shore, while a further three plaice died during the first 24 h. After three days of monitoring, 36 surviving caged plaice and three sole in healthy condition were transferred in the fish-monitoring system on board the Barentszee during the third trip (see below) and assessed as controls for the above experimental fish during three days at sea, before being released (Table 1).

2.3. Statistical analyses

The various technical (haul start time and duration), biological (catch volume and composition and fish TL) and environmental (sea condition and temperature and depth fished) data collected during the beam-trawl deployments by the Barentszee and Angel Emiel were treated as fixed categorical or continuous explanatory variables. Where there was sufficient replication, these variables were considered along with the random factors of 'months' and 'deployments' in two groups of generalised linear mixed models (GLMM) fitted to the immediate and short-term dichotomous status (alive vs. dead) of discarded plaice and sole. The fits were obtained using the lmer function in the lme4 package of the freely available (from http://cran.stat.auckland.ac.nz/) R language. For each analysis, a stepwise variable search algorithm was employed with the most