Fisheries Research 154 (2014) 120–126

Contents lists available at ScienceDirect

Fisheries Research

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

Quantitative video analysis of flatfish herding behavior and impact on effective area swept of a survey trawl

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ARTICLE INFO

Article history:
Received 1 July 2013
Received in revised form
23 December 2013
Accepted 7 February 2014
Available online 15 March 2014

Keywords:
Area swept
Flatfish
Herding behavior
Trawl surveys
Video-analysis

ABSTRACT

Uncertainty in fish behavior can introduce bias into density calculations from fishery-independent bottom trawl surveys that provide relative abundance estimates and population trends for stock assessments. *In situ* video was used to quantify flatfish behavioral responses to a bottom trawl sweep to improve the understanding of survey and assessment results. The behavior of 632 flatfishes was recorded during four tows. More than 90% of fish were observed in a perpendicular orientation away from the sweeps indicating a herding response. There was no significant effect of fish length on fish orientation or whether it reacted or remained stationary during the observation. Only 1.3% of fish were observed escaping the sweeps. A generalized linear model was used to estimate that at a distance of 73.8 cm (±3.4 SE) 50% of observed fish reacted to the sweep. The mean distance that stationary fish were first observed reacting to the sweep was 36.6 cm (±2.0 SE). Quantitative analysis indicates that flatfish herding occurs along trawl sweeps and the effective area swept is greater than the wing spread. Thus, the use of wing spread to calculate relative abundance estimates explains bias in stock assessment estimates of survey catchability that are greater than expected.

1. Introduction

An integral component of fisheries-independent trawl surveys is the ability to scale species-specific catch rates up to the larger population scale. The first step in this scaling process is a density estimate that incorporates species catch rate and area swept by the trawl. The area swept by the trawl is calculated using spread, which can be measured as the distance between the leading edge of the wings or the distance between trawl doors, and the distance traveled by the trawl (Dickson, 1993; Somerton et al., 1999; Fraser et al., 2007). The choice between the two spread measurements depends on an understanding of fish behavior in response to trawl sweeps and the availability of net wing or trawl door spread measurements. This choice affects the subsequent calculations of fish biomass.

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service, Northwest Fisheries Science Center (NWFSC) has been operating a trawl survey for groundfish stock assessments since 2003 (Keller et al., 2008). The trawl, rigging, and accessories are of a type commonly used in slope commercial fisheries, scaled to fit the class of vessels chartered for the NWFSC West Coast groundfish bottom trawl survey (WCGBTS) that range from 400 to 600 horsepower (Methot et al., 2000). The trawl configuration includes sweeps, defined here as the rubber disk encased steel core wire rope that extends from the trawl door to the footrope extension of the trawl, and includes both the mud gear and the lower bridle (as well as the “back strap” or “door leg extension”), with the goal to improve the herding of fish and to maintain desired net geometry (Fig. 1). Among the numerous species caught in the survey trawl, flatfishes, which have a strong affinity to the seafloor, are expected to have a herding behavior affected by the trawl sweep (Ryer, 2008). However, few studies have shown *in situ* evidence of herding for U.S. west coast flatfishes using a survey trawl with modified sweeps.

Behavioral work on flatfishes indicates that a predator avoidance response can be elicited by trawl gear (doors, sweeps and

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http://dx.doi.org/10.1016/j.fishres.2014.02.007
0165-7836/

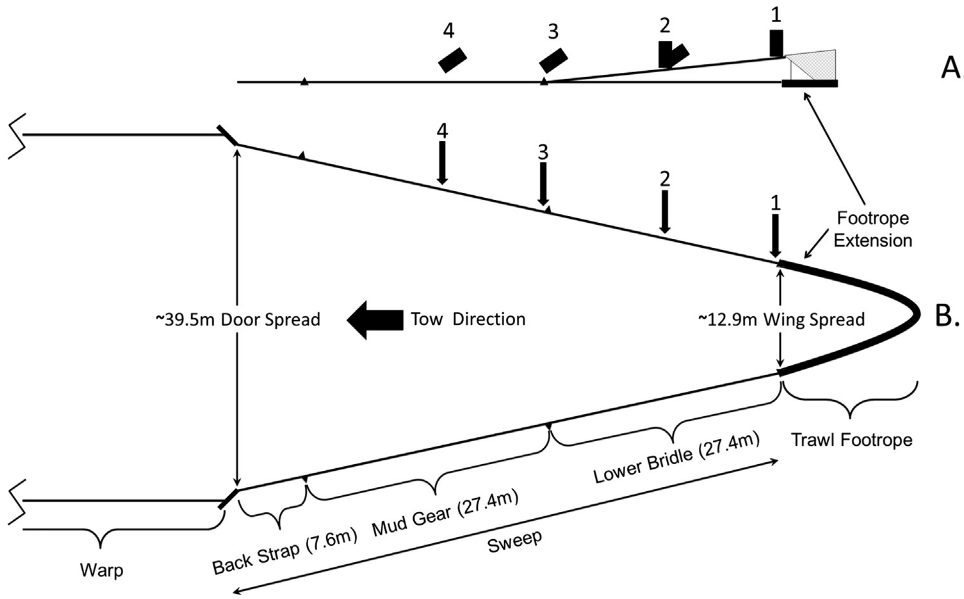

Fig. 1. Quasi-scale diagram of the Aberdeen-style trawl's footrope, bridles, mudgear, back strap, and doors under fishing conditions with indications of door and wing spread. The positions of the video camera system are marked with numerals 1–4.

footropes) and is the mechanism responsible for herding (Ryer et al., 2004; Ryer, 2008; Winger et al., 2010). The predator avoidance response, which differs among species, is characterized by a typically stationary flatfish rising off the bottom to flee a perceived threat (Ryer et al., 2004; Ryer, 2008). Early photography and video work along trawl sweeps suggest herding behavior (Main and Sangster, 1981; Wardle, 1983) and additional indirect studies comparing flatfish catches between modified gears suggest that herding occurs along the sweeps, but at different rates for different species (Somerton and Munro, 2001; Somerton et al., 2007).

The NWFSC trawl survey provides a relative index of abundance that is generated through the expansion of catch data using several calculations that are the same for all species. Species density is calculated for each tow by dividing the catch for each species by the area swept by the trawl. The area swept is calculated using the distance between the wings of the net (where the wing spread sensors are mounted at the leading edge of the wings) and the distance traveled by the trawl. An average density is calculated for each survey stratum and then multiplied by the area of that stratum to provide an estimate of the total stratum biomass. The sum of all stratum biomass estimates is considered the relative index of abundance.

The index of abundance for a given stock estimated from the trawl survey is related to the vulnerable biomass of the stock by a catchability coefficient (q), where q times the predicted vulnerable biomass from a stock assessment equals the survey index. Therefore, the actual value of the relative biomass estimate is not important to a stock assessment, but the relative change between each survey estimate is important. The estimate of q from a stock assessment is often expected to be less than 1, and when it is not, questions may arise as to why the expanded relative biomass estimate from the survey is greater than the biomass predicted by a stock assessment. Reasons for a greater survey estimate, i.e. $q > 1$, can include: (1) over-estimation of the density due to an incorrect area swept calculation, (2) expansion into un-sampled areas where the species does not occur (e.g. un-trawlable habitat), and/or (3) the predicted vulnerable biomass is incorrect.

This study addresses the possibility of an incorrect area-swept calculation generating a q larger than 1 by quantitatively investigating flatfish behavior in response to the sweeps used on the NWFSC Aberdeen-style bottom trawl. *In situ* video was used to examine the ability of the sweeps to evoke herding behavior in flatfishes on four experimental tows. *In situ* observations of movement, orientation, fish size, and distance from gear provide a better understanding of flatfish behavior and herding effects. This information may improve the understanding of the relationship between the area swept used to calculate the survey index of abundance and stock assessment estimates of q that are greater than expected.

2. Methods

2.1. Operations

The trawl-sweep herding experiment was conducted during 23–24 August 2009 in the northeast Pacific Ocean, off Newport, Oregon (44°37′ N 124°02′ W), at depths from 84 to 184 m using a 26-m chartered stern trawler, the FV "*Raven*" (Fig. 2). The vessel fished a standard Aberdeen-style trawl (online supplement 1–3) built and rigged to operate within strict specifications in compliance with protocols established for National Marine Fisheries Service bottom trawl surveys (Stauffer, 2004). Trawling procedures followed the NWFSC West Coast groundfish bottom trawl survey (WCGBTS) protocols (Keller et al., 2008), including towing only during daylight hours at a target vessel speed of 1.13 m/s. One deviation from normal WCGBTS protocols was a nominal tow duration of 12 min rather than 15 min which was done to maximize the number of tows within a limited amount of available ship time.

All fishing operations, including vessel operations and gear performance (spread between the leading edge of the wings, spread between doors, vertical distance from the center of the head rope to the bottom, distance from the head rope to the footrope, and clearance between the footrope and bottom), were monitored using a suite of trawl instrumentation systems. The tow officially began when the trawl was in proper fishing configuration and in contact with the bottom. The tow ended when the footrope lifted off the bottom after the start of haul back. Acoustic instruments were used to monitor ground gear contact during each haul in real time, but the actual bottom time was determined using data from a bottom contact sensor. Position data, collected at 2 s intervals for each haul, using a GPS-linked catch monitoring system (Simrad Integrated Trawl System and PI44 System), were used to monitor vessel speed over ground, track the vessel and trawl path, and estimate distance fished. Average trawl speed over ground and distance fished were