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Effects of mesh size and towing speed on the multispecies catch rates of historical swept area surveys

Luis M. Manjarrés-Martínez[a,*], Juan C. Gutiérrez-Estrada[b], José A. Hernando[c]

[a] Universidad del Magdalena, Facultad de Ingeniería, Carrera 32 22-08, 470004 Santa Marta, Colombia
[b] Universidad de Huelva, Departamento de Ciencias Agroforestales, 21810 Palos de la Frontera, Huelva, Spain
[c] Universidad de Cádiz, Facultad de Ciencias del Mar y Ambientales, 11510 Cádiz, Spain

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ABSTRACT

The use of different trawl nets is a factor to be considered when analysing historical swept-area research surveys aimed to characterize temporal variations in the relative abundance of demersal resources. If factors that may affect the performance of the bottom trawls were considered, more reliable temporal trends could be established. Due to the high species diversity that characterizes tropical areas, this kind of analysis is often carried out at the multispecies level. Therefore, the objective of this study was to establish the effect of two technical factors, mesh size and towing speed on the multispecies catch rates obtained in different demersal surveys carried out in the Colombian Caribbean Sea between 1988 and 2001, using two generalized linear models: one covering the entire study area and another restricted to one eco-region. For the global model, the effect of the mesh size on the multispecies catch rates was marginally significant ($p < 0.10$), unlike the towing speed, whose effect was not significant ($p > 0.10$). In contrast, for the eco-region model, the effect of mesh size was not significant ($p > 0.10$), while towing speed had a significant effect ($p < 0.05$). Size structure analysis showed escapement mainly through the codend meshes for the larger mesh size evaluated (50.8 mm), confirming the appropriateness of considering mesh size when analyzing historical data of swept area surveys. The effect of the towing speed, beyond the clear incidence on the area actually swept, point to the complexity of the relationship between speed and catch rates. In brief, the results showed that, when assessing historical databases, indices of relative abundance of tropical demersal resources can be improved by including mesh size and towing speed factors.

1. Introduction

In general, research survey cruises for assessing demersal fish stocks follow specific protocols that try to minimize the effect of the variables that are not considered in the calculations inherent to the swept area method. It is, however, relatively common that some technical and operational characteristics vary between historical surveys in a region. One of these technical variables is the mesh size used at the codend of the net. This variable is crucial in determining the escape or loss of fish through the nets (Ragonese et al., 2001; Weinberg et al., 2002; Weinberg and Kotwicki, 2008). A second operational variable to take into account is towing speed (Dahm et al., 2002; Weinberg et al., 2002), which may vary significantly over a survey, due to many uncontrollable factors, generally environmental, that modify the functioning of the net (Weinberg et al., 2002; Herrmann, 2005a,b; Duarte and Cuello, 2006). The impact of this variable, as well as that related to the calculation of the swept area, is essential in three basic processes of bottom trawling: (i) horizontal herding, stimulated by sand clouds and the bridles; (ii) vertical herding, in response to stimuli such as the headrope or boat noise; and (iii) fish loss or escapement under the footrope (Weinberg et al., 2002; Weinberg and Kotwicki, 2008). Generally, the effect of these aspects is analysed by a video camera attached to the trawl (Somerton and Weinberg, 2001), since it is difficult to define a measurable variable that can, by itself, reflect the effect of the horizontal herding or the vertical herding.

Other factors that generally vary between historical surveys are tow duration and net size. Although tow duration is a variable considered in the swept area method (Ye et al., 2005; Catalán et al., 2006), it has been proposed that this variable also has an influence on the size structure of the catch, on the basis that the largest individuals are able to swim ahead of the net for longer periods of time

* Corresponding author. Tel.: +57 5 4217940; fax: +57 5 4301292.
E-mail addresses: lmanjmart@hotmail.com, lmanjarrez@unimagdalena.edu.co (L.M. Manjarrés-Martínez), juanc@uhu.es (J.C. Gutiérrez-Estrada), joseantonio.hernando@uca.es (J.A. Hernando).

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(Sparre and Venema, 1998). However, several studies have failed to find a significant relationship between tow duration and catch size distribution (Godo et al., 1990; Walsh, 1991; Somerton et al., 2002). According to Godo et al. (1990), this is due to the fact that at the beginning of the tow, before a school is established at the mouth of the net inducing an alert reaction in the fishes, the effect of exhaustion is less important than that of surprise.

With respect to net size, the horizontal opening of the trawl net is considered through the calculation of the swept area (Ye et al., 2005; Catalán et al., 2006; Bergstad et al., 2008). Regarding the vertical opening of the trawl net, in controlled experiments with two different heights of vertical opening, Johnson et al. (2008) did not find statistically significant differences in the number of individuals of the main fish taxa that were caught, or the structure and composition of the assemblages. In contrast, the mean catch per unit effort (CPUE) was greater in the net with a larger opening height, though this trend was most clear for certain pelagic fish taxa that form large shoals.

The ability to use fish catch rates obtained from scientific surveys as relative abundance indices depends on the feasibility of removing effects other than abundance, a process that has been described as "standardization of catch/effort" (Maunder and Punt, 2004). Therefore, we should analyze the effect on the catch rates of those factors that influence the trawl performance as a prerequisite for properly calculating estimates of relative abundance that reflect changes in population distribution and density (Weinberg and Kotwicki, 2008).

It is known that behaviour and swimming performance of different species can vary greatly (Winger et al., 2004; Queirolo et al., 2012) and therefore it would be recommendable to analyse the effect of the mesh size and towing speed at the species level. However, it is also known that analysis of the status of tropical demersal fish resources is usually made at multispecies level, supplemented with analysis of species composition, due to the extremely high species diversity that characterizes this type of surveys in tropical areas (Blaber et al., 1994; Sparre and Venema, 1998). In fact, the fish bycatch of the shrimp trawl fishery operating in the Colombian Caribbean Sea (CCS) is composed of 175 taxa distributed in 58 families (Viaña et al., 2004), while the database of the surveys carried out in the CCS between 1988 and 2001 reports a total of 311 taxa of demersal fish (Duarte and Cuello, 2006). Therefore, the objective of this study was to analyze the effect of the mesh size and towing speed on the multispecies catch rates in historical demersal fish assessment surveys performed in the CCS. Both generalized linear models (GLMs) and generalized additive models (GAMs) offer a powerful tool for achieving this objective, since these models allow more flexible linear predictors as well as automatically control the parametric complexity (Venables and Dichmont, 2004). However, we chose GLMs because a significantly better fitting was not obtained using GAM models, in spite that this technique includes local smoothers as terms.

2. Materials and methods

2.1. Data sources

We used data collected from eight fishery-independent trawl surveys for the assessment of demersal fish stocks conducted in the CCS during the period 1988–2001, which were all based on the swept area method. Specifically, the study was based on the four surveys carried out in 1988 under the framework of the NORAD-UNDP/FAO programme (Strømme and Sætersdal, 1989), the three in 1995 and 1996 under the INPA-VECEP/UE programme (Manjarrés et al., 2005a,b,c) and the survey in 2001 under the INPA-COLCIENCIAS programme (Duarte and Cuello, 2006) (Table 1). A total of 333 fish taxa were found in the 331 hauls carried out in the eight cruise surveys (18 taxa per haul in average, coefficient of variation 73.5%, maximum number of taxa per haul, 79). A total of 21 taxa accounted for 70% of the total catch by weight, the most abundant species being three lutjanids (*Lutjanus synagris*, *Lutjanus analis*, and *Rhomboplites aurorubens*).

As well as the catch rates, the following information was available for each haul: date and time, initial and final latitude and longitude, initial and final sampling depths, tow duration (minutes), average towing speed (Table 1) and basic characteristics of the trawl net used (Table 2). For all surveys, the protocol for determining initial and final latitude and longitude data was based on the navigator's estimate of the position when the gear made bottom contact after shooting and when gear began to be hauled by the winch, respectively (Sætersdal et al., 1999; Manjarrés et al., 2005a,b,c).

For all surveys net spread (wing tip to wing tip) was used as a measure of the horizontal opening required for estimating swept area. However, in none of the various reports on UNDP-FAO-NORAD survey cruises the methodology for establishing horizontal opening is mentioned. For INPA-VECEP/UE and INPA-COLCIENCIAS surveys (cruisers made by our research group), a model of the relationship between warp length and depth was made, based on a horizontal opening goal of 60% (as recommended by the manufacturing company of these trawls). Both during the previous calibration and for some hauls of the cruises, the horizontal opening was estimated by applying the trigonometric method used for stern trawlers (Okonsky, 1972). In this method, first the distance between otterboards is calculated by relating the distance between the towing blocks and the distance between the towing warps at a fixed distance from the towing blocks. Then, the approximate horizontal opening of the headline is estimated by applying the formula of similar triangles that involves the following measures: distance between otterboards, length of sideline, length of wing bridles (legs) and length of ground bridles. The model showed a good performance in those hauls where the Okonsky's method was again applied during the surveys (at different depths), in the sense of obtaining a horizontal opening of about 60%.

Target speeds were the same for INPA-VECEP/UE and INPA-COLCIENCIAS surveys (3.5 knot), although, as it is common in demersal surveys, towing speed ranged between 1.5 and 4.5 knot (Manjarrés et al., 2005a,b,c; Duarte and Cuello, 2006). Documents related to UNDP-FAO-NORAD surveys do not specify a target speed. What is only possible to state is that UNDP-FAO-NORAD survey speeds ranged between 0.6 and 4.5 knot (Strømme and Sætersdal, 1989).

2.2. Pre-processing of data

A database editing and screening stage was carried out prior to the modelling stage, for quality assurance. The original database comprised a total of 313 hauls (Table 1), but 18 hauls were eliminated due to very short towing durations (<0.2 h) and 6 more hauls were excluded due to low towing speeds (<1.5 knot), which may mean the risk of otterboards malfunctioning. This prep stage also included the standardization of the scientific names across surveys, given the time elapsed between the different cruises.

Because the data came from cruises conducted with trawl nets of different sizes (Table 2), catches were normalized to a standard area (SA) of 0.04 km^2 to be able obtain the catch per standard area (CPSA) (Rogers and Ellis, 2000; Helser et al., 2004; Ye et al., 2005; Catalán et al., 2006; García et al., 2007; Bergstad et al., 2008). The SA was calculated on the basis of the shortest horizontal spread in the surveys (12.6 m), an effective tow duration of 30 min and a towing speed of 3.5 knot. In this way, potential bias associated with spatial extrapolation was avoided (Kirchner and McAllister, 2002).