APPLICATION OF GENERALIZED LINEAR MODELLING TO THE STUDY OF CATCH RATES OF WESTERN MEDITERRANEAN TRAWL FLEETS

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Abstract

Generalized Linear Modelling (GLM) techniques are used to develop a model for catch rates of European hake by the Spanish trawl fleet fishing off the coast of Castellón (E Iberian Peninsula) between 1991 and 1996. The model includes a factor for vessel category of GRT, as a means of adjusting for fishing power effects, as well as factors for year, month and fishing closure effects. Vessel capacity, season and year are shown to have a significant effect on hake catch rates of this fleet, with vessel capacity alone explaining about 54% of the total variation in the data. Significant first order interactions are found between all three effects with only the year by month interaction being highly significant and probably related to the varying timing of the bimonthly annual closure of the fishery. The model explains 63% of the variation in the CPUE data, an amount similar or above that obtained by other authors. Introduction of additional factors, such as location, skipper ability and knowledge, vessel specific improvements in fishing technology or any other determinants of fishing power, and effects of other species in the model, may be used to reduce the amount of unexplained variation and therefore to increase the reliability of the derived abundance indices.

Key-words: demersal, fishes, trawl surveys, stock assessment, Western Mediterranean

Introduction

Groundfish trawl fishing is widely spread all over the Mediterranean. At present, there are about 1234 trawlers operating off harbours along the Spanish Mediterranean littoral (1) with annual landings reaching 60 000 t. Although these are multispecies fisheries -up to 40 different species may appear in the landings- a small number of them account for a large proportion of the catch and of its economic value. The main target species are: European hake (*Mercluccius merluccius*), red mullet (*Mullus barbatus*), sole (*Solea solea*), monkfish (*Lophius* spp.), octopus (*Octopus vulgaris*), squid (*Loligo vulgaris*), cuttlefish (*Sepia officinalis*) and red shrimp (*Aristeus antennatus*). Due to the multispecies nature of the fisheries and the large number of landing harbours involved, it has been traditionally difficult to gather long and reliable series of data of the activity and catches of the fleets which would allow to carry out stock assessments. Fisheries management tools applied in Spanish Mediterranean groundfish trawl fisheries are effort controls (12 hours fishing per day and a maximum power of 500 HP), permanent closure above 50m depth, minimum mesh size, minimum landing sizes, and since 1991 a two-month spring-summer closure in certain areas (*i.e.* off Castellón).

For fisheries where only series of catch and effort data are available, catch per unit effort (CPUE) information from commercial fishing vessels is frequently used as biomass indices for stock assessment purposes. For most stocks, indices are averaged across fishing gears, areas, months and then within years to produce indices of annual abundance (2). However, given the tendency of fleets to increase their efficiency with time, it is not easy to obtain reliable standardized measures of the effective effort through the years. A number of factors contribute to this. In addition to changes in fleet composition and changes in fishing power of individual vessels, factors such as fishermen behaviour and market prices may also contribute to increasing or reducing the effective effort exerted over any particular stock in a multispecies fishery. Seasonal fluctuations in abundance or availability due to changes of fish behaviour or oceanographic conditions, also influence catch rates of a given species.

A method based on a multiplicative model for CPUE developed by Robson (3) has proven useful for obtaining standardized catch rates when appropriate information is available (4, 2). The multiplicative model relates the catch rate of a certain vessel type (i) at a certain time (t) to the catch rate of a reference vessel (v1) at a reference time (t1), times a factor which is the abundance in time (t) relative to that of time (t1), times a factor which is the efficiency of vessel type (i) relative to that of vessel type (v1). The model can accommodate effects such as year, area, season, and fishing power. The coefficients of factors can be estimated by using Generalized Linear Modelling (GLM). This method has been widely applied for the standardization of CPUE indices in the tuna fisheries managed by the ICCAT(4,5) and to a lesser extent to groundfish fisheries for, *e.g.*, *Gadus morua* (6), *Sebastes alutus* (7), *Solea solea* (2).

Objectives

This study uses linear multiplicative models to describe and estimate the CPUE of European hake (*Merluccius merluccius*) from Spanish trawlers fishing off the coast of Castellón (E Iberian Peninsula). Catch rates, defined as average daily catch, have been modelled taking vessel characteristics (capacity), time (year), season (month) and fishing closure as factors. This analysis is intended to: a) improve our knowledge of factors affecting hake trawl catch-rates, and b) investigate methods to obtained annual standardized abundance indices. European hake (*Merluccius merluccius*) has been chosen for the study due to its importance in the trawl fleet landings (12% in weight of Castellón total in 1995) and its high economic value (21% of Castellon total first sale value in 1995). The trawl fleet which operates from the harbour of Castellón is singled out as a case study in the wider context of the Western Mediterranean groundfish trawl fleets.

Material and methods

The data set of the trawl fleet operating from the harbour of Castellón contains vessel monthly landings of 21 commercial species and groups of species together with the number of days fished and vessel characteristics (GRT, HP, and length) for the 36 vessels making up the fleet during the period of 1991 to 1996. These data have been gathered by the Instituto Español de Oceanografía sampling and information network.

Tonnage (GRT) is chosen as the most relevant vessel characteristic reflecting fishing power for this fleet instead of the more commonly used horse-power (HP). GRT and HP data available are nominal values and for HP they are known to depart significantly from the effective values. This is because since power is regulated and also taxes are paid accordingly, there is an incentive to conceal the real power of the vessel. To corroborate this, the relationship between nominal GRT and HP was examined. On this basis and pursuant to the examination of the GRT/HP plot, vessels were grouped into three categories of nominal GRT: <35, 35-55 and >55 GRT. For each combination of vessel, month and year, catch rates were calculated as the total recorded landings of hake (assumed equal to catches since discards of this species can be considered negligible (data from IEO/EU project 94/027) divided by the total number of days fished.

To investigate the effect of fishery vessel type together with annual and monthly variation on catch rates from the hake trawl fishery, generalized linear models (GLMs) (8) were applied using routines contained in the S-Plus programming environment (9). A gamma distribution was used in the analysis since the frequency distribution of the catch rates was skewed and the variance proportional to nearly the square of the mean weight (9). The gamma density function is expressed within generalized linear models in terms of the mean μ and the parameter ν which determines the shape of the distribution. The parameter ν, assumed constant for all observations, is σ^{-2}, where σ is the coefficient of variation. The gamma variance $V(\mu) = \mu^2/\nu$, and a logarithmic-link $\log(\mu)$ functions were used to relate the expected catch rates to the predictors. Independent variables vessel class, year, month and fishing closure were introduced as factors. The following generalized linear model was used

$$\ln(\mu_{ijkl}) = f + \beta_i^I + \beta_j^J + \beta_k^K + \beta_l^L$$

where μ_{cmyp} is the expected catch for vessel class c, month m, in year y and following or not a closure period p. Analysis of deviance to evaluate the significance of the factors in the model was performed by comparing models excluding one term at the time.

Summary of main effects

Main effect	Data
Vessel category (GRT) (c)	< 35, 35-55,> 55
Year (y)	1991,1992,1993,1994,1995, 1996
Month (m)	12 months of the year
Closure period (p)	Yes, No

Results and discussion

Table I shows the results from the analysis of deviance which indicates that differences in catch rates between vessel classes is significant and also the variation with month and year (probability of F <0.0001). Conversely, catch rates are not significantly affected by the fishing closure term (probability of F>0.2). Monthly variation differs between vessel classes and also between years (probability of interactions < 0.05). The model incorporating all independent variables and interactions reduces de null deviance