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Study of swordfish fishing dynamics in the eastern Mediterranean by means of machine-learning approaches

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Abstract

We analyzed fisheries data collected in 2000 and 2001 from the Greek swordfish fishing fleets operating in the eastern Mediterranean, by means of machine-learning approaches, in order to define differences in exploitation patterns and fishing strategies. Based on their total annual catch, fishing vessels have been classified in three groups: low, medium and high producers. Decision-tree analysis revealed that group membership could be successfully predicted from the total number of working days per year, the vessel length, the type of gear used, the hook size and the number of hooks per set. Using the data of 2001 as a test data set and assuming that only the average catch of the most productive group was known, total production estimates for that year showed very little difference (7.92%) from the true values. These findings indicate that simple sampling schemes focusing on the high producers may be adequate for the examined fisheries. They also provide evidence that such methodological approaches could be useful for the cross-checking of fisheries estimates obtained through various sampling schemes.

Keywords: Swordfish; Machine learning; Fishery; Mediterranean

1. Introduction

The swordfish, *Xiphias gladius* (Linnaeus, 1758), is a commercially important highly migratory fish, globally distributed between the latitudes 45°N to 45°S (Palko et al., 1981). Mediterranean swordfish populations constitute a unique stock (Kotoulas et al., 1995, 2003) having different growth and maturity characteristics from the adjacent Atlantic ones (Cavallaro et al., 1991; Ehrhardt, 1992; Tserpes and Tsimenides, 1995). The swordfish fisheries in the Mediterranean are characterized by relatively high catch levels and the annual reported catches (on average 14,500 tonnes from 1984 to 2002) are similar to those observed for larger marine areas, such as the North Atlantic (Anonymous, 2003). The latest assessment carried out by the International Commission for the Conservation of Atlantic Tunas (ICCAT) estimated the total biomass of the Mediterranean stock to be around to 40,000 metric tonnes in the last few years (Anonymous, 2003).

The Greek swordfish fishery started developing in the early 1980s and nowadays Greek fleets exploit a large part of the E. Mediterranean basin extending their activities from the east Ionian to the Levantine Seas (Tserpes et al., 2003a,b). Recent ICCAT catch records indicate that Greece together with Italy, Spain and Morrocco are the most important swordfish producers in the Mediterranean (Anonymous, 2003). Fishing is carried out by means of drifting longlines and the fishing season lasts from February to September, as a fishery closure aiming to the protection of juveniles is enforced from October to January through a national regulation. Two different longline types are used: the Classical and the so-called American, owing its name to its similarity to the longline used for tuna fishery in the Atlantic. The main differences between the two types concern the length and diameter of mainline and branch lines, as well as the distance between branch lines. Detailed

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descriptions of the Greek swordfish fishery have been presented elsewhere (e.g. Tserpes et al., 2003a,b; Tserpes and Peristeraki, 2004).

Although there are several studies dealing with the biology, dynamics and fisheries of the Mediterranean swordfish (e.g. Cavallaro et al., 1991; Tserpes and Tsimenides, 1995; De La Serna et al., 1996; Tserpes et al., 2001a,b, 2003a,b; Stergiou et al., 2003) information on the fishing strategies and tactics of the various Mediterranean fishing fleets is very limited (Katselis et al., 2000, 2001).

As fishing strategy and tactics involve various heterogeneous factors, such as the target species, gear-type, number of days at sea etc. they can influence the exploitation pattern in different ways (Hilborn and Ledbetter, 1985; Pelletier and Ferraris, 2000; Maynou et al., 2003). Thus, a typology of fishing tactics is useful for: (a) classifying into components fleets having comparable impacts on the resources (Mesnil and Shepherd, 1990; Rogers and Pikitch, 1992; He et al., 1997; Biseau, 1998; Jabeur et al., 2000; Le Pape and Vigneau, 2001; Maury and Gascuel, 2001; Silva et al., 2002); (b) improving knowledge on the impact of a fishery to the ecosystem (Lewy and Vinther, 1994; Biseau, 1998; Ulrich et al., 2001); (c) building dynamic fishery models (Murawski and Finn, 1989; Laurec et al., 1991; Laloe et al., 1996; Marchal and Horwood, 1996; Millischer et al., 1999); (d) designing sampling schemes able to provide accurate and precise estimates, necessary for fisheries monitoring (Laurec and Shepherd, 1983).

In the present work, we analyze data from commercial swordfish fisheries in order to identify discrete fishing strategies for the Greek fleets targeting swordfish in the E. Mediterranean basin. Data are analyzed by means of up-to-date supervised machine-learning approaches that allow concurrent examination of both quantitative and qualitative factors affecting catches of commercial vessels. The method, which has not been previously used for the analysis of such data, has the advantage of being free from any distributional assumptions implicit in classical multivariate analysis. This approach can provide indirect estimates, useful for evaluation purposes, in cases where direct information provided by the fisheries monitoring schemes is questionable. Such a situation is common in several fisheries, including Mediterranean ones (Papaconstantinou and Farrugio, 2000).

As various technical measures, including minimum landing size regulations and spatiotemporal closures, have been proposed to preserve sustainability of the Mediterranean swordfish stock (Di Natale et al., 2002; Anonymous, 2003), such a study would assist optimization of operational sampling schemes and adoption of management actions taking into consideration fishers' behaviour and preferences.

2. Materials and methods

Swordfish fisheries data from the Greek fleets operating in the eastern Mediterranean were collected during the 2000 and 2001 fishing seasons from vessels based at the main landing ports of the two major fishing areas: Ionian and Aegean seas (Fig. 1). Previous studies have shown that landings at these ports represent more than 70% of the Greek swordfish fishing production (Tserpes et al., 2003a). The collection of data was accomplished on a trip basis and included: landings in terms of weight, number of fishing days, type of long-line used (Classical or American), number of hooks per set, and hook size. Three categories of hook sizes were considered based on their lengths: small (length up to 5 cm), medium (length in the range of 5–7 cm) and big (length over 7 cm). Besides the vessel length, as it was mentioned in the fishing licence, was recorded. Sampling covered 58 vessels in 2000 and 49 in 2001. Collected data were compiled to obtain, for each vessel, annual estimates of: (a) total catch, (b) total number of fishing days, (c) mean number of hooks per set, (d) vessel length, (e) hook size category, (f) long-line type, and (g) major landing area.

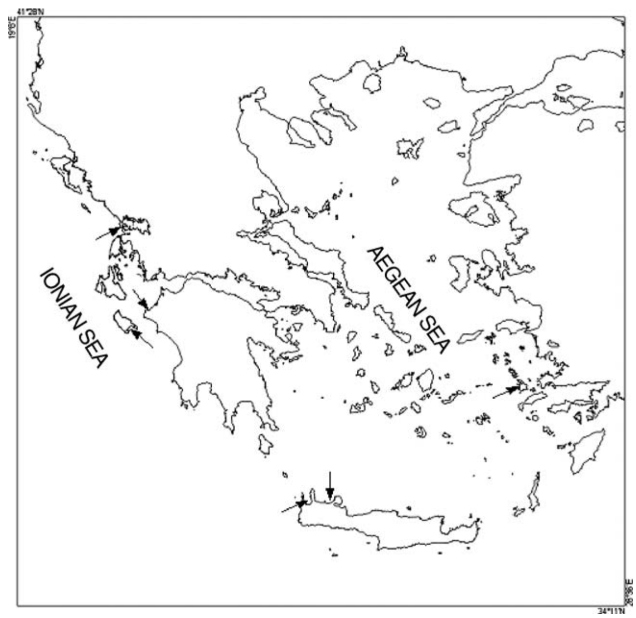

Fig. 1. The studied fishing areas (Aegean, Ionian seas). Arrows indicate the position of the sampled main landing ports.

Based on their total annual catch, vessels were classified in three classes: A = low, with production less than 2500 kg, B = medium, with production ranging from 2500 to 8500 kg and C = high, those having production higher than 8500 kg. This classification scheme was based on past information regarding the productivity of the Greek swordfish fishing fleets (Katselis et al., 2001).

Supervised machine-learning approaches (Mitchell, 1997), and in particular the decision-tree construction method (Quinlan, 1986) as implemented by the C4.5 algorithm (Quinlan, 1993), were employed to identify the power of the aforementioned examined features (attributes) in classifying the vessels into the pre-defined production classes. The algorithm was applied following a bagging procedure (Breiman, 1996). According to the method, which relies on