An overview of the FADs fishery in the Mediterranean Sea

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Abstract

The Mediterranean small-scale fleet is highly adaptive, showing a dynamic fishing intensity and strategy, and exploiting seasonal abundant resources. In this area, the aggregatory behaviour under floats of juvenile fish has been used since ancient times to exploit oceanic migratory species such as dolphinfish (*Coryphaena hippurus*), using Fish Aggregating anchored Devices (FADs). A total of 2 300 boats are engaged in this fishery from August to December, the main fishing areas being those around Malta, Tunisia, Sicily and Majorca.

The FADs (~1m^2) are made of different cheap floating materials, and are moored in fixed places, ranging from shore waters to areas 60 miles off the coast (1 500 m depth). Each boat deploys an average of 20 to 100 FADs. The gears used are special surrounding nets without purse line, and traditional purse seine nets.

The fishery exploits young-of-the-year dolphinfish (<6 months old), originated by a pre-spawning migration of adults from Atlantic waters. Their catches show high annual and monthly variability, depending on the recruitment and the accessibility of recruits to the fishery. Pilotfish (*Naucrates ductor*) and greater amberjack (*Seriola dumerili*) are also exploited in this fishery as by-catch.

A total of about 1 000 metric tons of dolphinfish are yearly caught mainly in September-October. The FADs are historically laid in August. Recently, the FADs fishing period has increased in Sicily, and the FADs are laid in July, so as to catch pilotfish and greater amberjak juveniles. In recent years, the interest for this fishing method and the study of these fisheries has increased in the Mediterranean. Though the market and its seasonality limit this exploitation, this fishery is economically profitable with good revenue.

Introduction

Mediterranean small-scale fishing is a variable activity with fishing intensities and strategies showing very rapid fluctuations in space and time and highly multispecific catches. The seasonal activity of the fleets is related to the ecology of the different species, to meteorological conditions, tourism season, etc. In order to quantitatively assess the Mediterranean small-scale fisheries, one of the main problems is to evaluate in space and time the elementary fishing efforts and yields of every component, and their corresponding variations. These elements are essential for the evaluations of fishing effort and global production, which are of paramount interest for the studies of the fisheries and exploited resources dynamics (Farrugio & Le Corre, 1993).

Dolphinfish (*Coryphaena hippurus*) is exploited using FADs (Fishing Aggregating Devices) in two main Mediterranean areas, Western Mediterranean (Majorca Island) and Central Mediterranean (Sicily, Malta Island and Tunisia). This activity is practised in the same period and by similar procedures and equipment (Galea, 1961; Lozano-Cabo, 1961; Lleonart *et al.*, 1999; Massutí *et al.*, 1999). There is no documented information for other Mediterranean areas. These dolphinfish fisheries have been developed since ancient times, as shown by a mural painting from Thera dated from Minoic times. The activity in Majorca is documented from the 14th century (Massutí & Morales-Nin, 1997) and from Malta from the 18th century (Farrugia-Randon, 1995).

At the end of summer and during the autumn (August-December), dolphinfish are caught by a large number of vessels using surrounding nets to capture fish under the FADs typical of the Mediterranean (Bono *et al.*, 1998; Missaoui & Chakroun, 1997; Pla & Pujolar, 1999). The FADs are used to increase the availability of this migratory oceanic fish resource through the creation of productive target fishing locations. The main by-catch are pilotfish (*Naucrates ductor*) and amberjack (*Seriola dumerili*).

The captured dolphinfish are juveniles (less than 6-month old) (Massutí *et al.*, 1999; Morales-Nin *et al.*, 1997) resulting of a local spawning in spring-summer (Massutí & Morales-Nin, 1995). The spawners are originating from Atlantic waters (Pauly, 1987) and emigrate in the Mediterranean when the water temperature is over 16°C (Massutí & Morales-Nin, 1991). The adult dolphinfish (age 1+) are also by-catch in albacore and swordfish fisheries (Lozano-Cabo, 1961; De Metrio *et al.*, 1997).

In this review paper, we describe in detail the available data on the FADs fisheries by area and summarise the exploitation data in the Mediterranean. The data presented for Sicily and Majorca have been collected in the frameworks of "Biology and fishery of dolphinfish in the Western Mediterranean and Canary Islands area" and "Dolphinfish biological and fishing data in the Western Mediterranean", funded by Directorate General XIV of the European Commission (94/031 and 95/73, respectively). The data from other Mediterranean areas have been presented during a symposium held as a part of the above mentioned projects.

Fleet and fishing operations

Majorca Island

In Majorca, around 45% of the small-scale fleet are engaged in three main seasonal fisheries directed to *Aphia minuta* from December to March, *Palinurus elephas* from March to August, and *Coryphaena hippurus* from August to December. Other small-scale fisheries developed at the Island are targeted on cuttlefish (*Sepia officinalis*), common seabream (*Pagrus pagrus*), common dentex (*Dentex dentex*), great amberjack (*Seriola dumerili*) and squid (*Loligo vulgaris*), using a combination of different gears (Galea, 1961).

The fishing ports, FAD mooring areas and FAD number by area in Majorca Island are shown in figure 1. A total of 46 boats took part in this fishery in the 1995 fishing season and 37 in 1996. On average, the boats are small, with 8.3 m mean length, 5.6 GRT displacement and 64.0 HP of engine power. Except in Port de Sollér, all the boats are equipped with one or two hydraulic net winches. The fishing master (generally the owner) and one or two fishermen are aboard these boats, except in Port de Sollér where the crew is more numerous (4 or 5 men). The number of boats per port is around eight, except in Palma (3) and Port d'Andratx (4). The available data for ten years show a more or less constant boat number with a mean of 50 boats per year directed to this fishery.

Each year the individual mooring places (fig. 1) inside each mooring area are distributed by port among the boats registered for the year's fishery. Each boat deploys on average 30 to 40 FADs at its mooring location, except Port de Sollér with 20 to 28 FADs per boat. This port is exceptional because after fishing in the mooring areas, they spend most of the time looking for drifting floating objects and fish around them. The mooring areas of each port are located at depths over 70 m and may reach a maximum of 1,200 metres. All harbours have one mooring area per boat (fig. 1), except Port de Pollensa and Cala Rajada where there are two. The mooring areas of Port d'Andratx, east of Dragonera Island, and of Palma on Palma bay, are not used due to conflicts with the longline fishery for swordfish (*Xiphias gladius*) (areas with lighter shadowing, fig. 1).

In Majorca each boat visits daily at sunrise its FADs, weather permitting. Once the presence of fish is detected under the FADs, using a trolling line or visually, a quick haul is carried out with the net close to the FAD on the boat board side. If the weather is calm and if there is no current, the haul is done around the FAD. If the catch is insufficient, the fishermen search for floating debris to increase it.

The fishing areas may be visited again at sundown depending on the daily catch and dolphinfish abundance. The success of the first fishing operations of the day determines the number of FADs which are visited. The fishermen may choose only a part of the mooring area for fishing, depending on wind and current conditions, or on their estimate of the place with best chance of a catch.

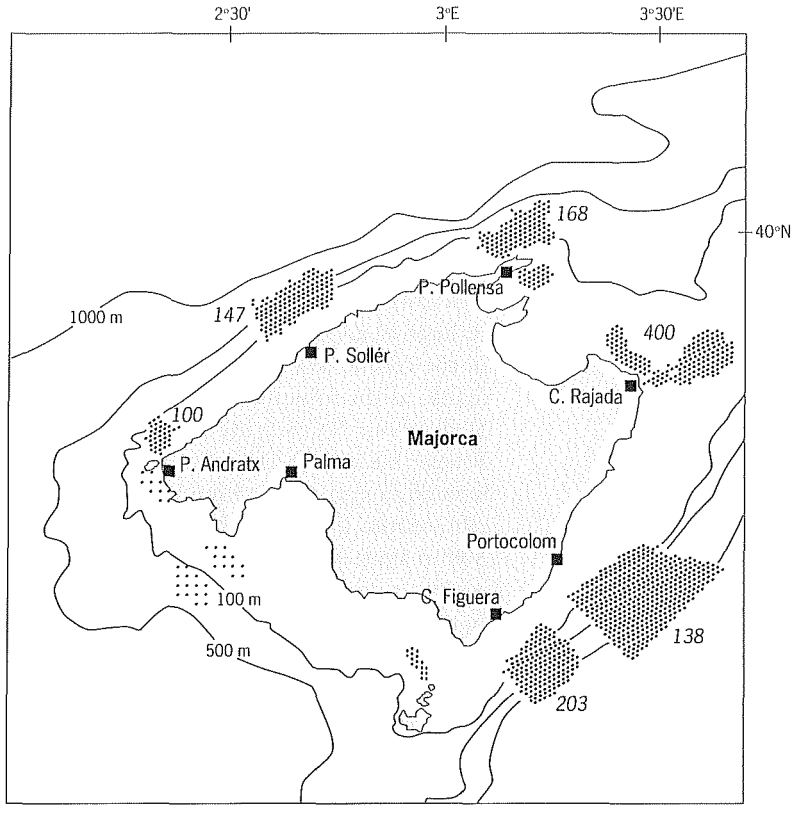


Figure 1
Traditional mooring areas, number of FADs by area and fishing ports on Majorca Island. Lighter shadowing: areas not used (from Lleonart *et al.*, 1999).

The gear for dolphinfish is a special surrounding purse net without a purse line, called "llampuguera". The average net size is 180 m length and 16 m depth (Massutí & Vidal, 1997).

Sicily Island

The boats of West Sicily (57) have an average overall length of 9.85 m and a gross tonnage of 5.76 tons, while those of East Sicily (168) have an average of 11.41 m and an average gross tonnage of 10.42 tons. The low average size of the boats of West Sicily is due to some small boats which fish near the coast. The fleet of East Sicily is represented by larger boats which only perform this type of fishing for a limited period of the year. In other periods, they engage in fishing activities in which the length, tonnage and engine power have considerable importance, such as longline and drifting-net fishing for swordfish, and purse seining for small pelagics. In West Sicily, the smaller fishing boats are engaged in fishing dolphinfish from September to December. During the other months, they fish using "tremel-net", bottom longlines or gillnets and drift-gillnets for small and medium-sized pelagics.

Figure 2 shows the geographical arrangement of the FADs per port; the lines have been drawn on the basis of knowledge of the co-ordinates

of the two outer FADs, the total number of FADs and the average distance between the FADs. Each line represents the fishing area by single fisherman.

Depending on the area, the FAD deployment varies. Thus, in the Castellamare Gulf, the boats lay approximately 110 FADs in a corridor of sea extending between 0.5 km and 11 km from the coast. The FADs are spaced 300 m apart and are examined periodically, weather permitting. In Capo San Vito-Capo Feto each boat lays about 50 FADs. The area where the FADs from San Vito Lo Capo fleet are deployed extends through an arc of 180° and a radius of about 25 km with Capo San Vito in the centre. The FADs are laid within this area depending on the depth, as the fishermen do not lay them over 500 m depth. In West Sicily about 50 FADs are moored in August. The FADs used in the Pelagic Islands are very similar to the Maltese ones. These FADs are moored in a strip stretching from the coast for 40 km, following specific routes. Each boat drops between 10 and 50 FADs spaced about 300 m from one to another. Fishermen usually go out at dawn and return at dusk, after having examined all the FADs.

In the Tyrrhenian Sea, the fleet uses anchored FADs except in Termini Imerese and Porticello where the boats use drifting FADs. In the case of these latter fleets, the area fished is much larger than the area occupied by anchored FADs. In the zone between Capo Milazzo and Capo di Orlando, the area where the FADs are distributed is bounded in the north by the Aeolian Islands, which also represent the limit of FADs

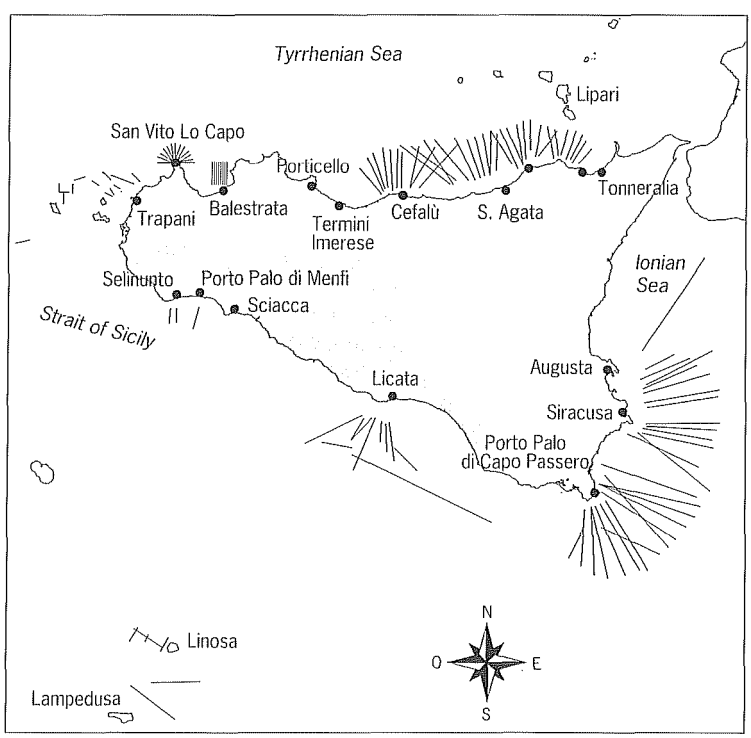


Figure 2
Mooring areas by ports in Sicily. The lines indicate the position of the groups of FADs (from Potoschi *et al.*, 1999).

positions for the Tyrrhenian area (fig. 2). In this area, the total number of FADs used by each boat ranges between 40 and 80, and the mooring anchorage depth does not exceed 600 metres. In the Ionian coast of Sicily, the sea is deeper, thus positioning FADs is more difficult due to the amount of wire needed to secure them to the sea bottom and to the weight of the ballast required. There are 60 to 100 FADs per boat, and the distance between them is approximately 800 m, the anchorage depth may overpass 1,500 m (Pla & Pujolar, 1999). The total number of FADs has strongly increased in the recent years (6,000 in 1990, 13,000 in 1998, 19,000 in 1999). This increase is due to the irregular drift net catches and the biological closure of some pelagic fish fisheries.
The typical net used in Sicily, known as "lampugara" or "caponara", has a length of 180 m, a height of 45 m, one float every 0.14 m and 900 weights weighing 90 kg in all. Though not corresponding exactly with the dimensions of the vessels, the dimensions of the nets increase generally with their gross tonnage.

Malta Island

The dolphinfish is one of the more important species for the economy of the Maltese fishing industry. In fact, until the recent years, it was the most important fishery due to its traditional interest on the local market and the abundance of catches which regularly occur each year (Bussuttil, pers. comm.). Most of the Maltese fleet operate in coastal and small-scale fisheries and very few operate in larger scale or in open seas (Galea, 1961). In 1998, the total number of fishing licensed vessels were 1 792 (1 475 in Malta and 317 in Gozo). Beyond these only 47 overpass 15 m in length. The larger industrial vessels are mainly trawlers, longliners and netters. All the other smaller vessels are considered as multipurpose and undertake different types of seasonal fishing activities, including dolphinfishing. The total number of boats and fishermen currently involved in this fishery are 111 boats and 550 fishermen (Potoschi & Sturiale, 1996).
During the month of May, all boat owners whose craft is longer than 6 m are invited to submit applications for the allocation of a fishing site. When all applications have been received, these are apportioned into different ports/districts. A licence for using a particular fishing site is then issued by the Department of Fisheries. The FADs are laid from 1st of August but the fishing season starts on the 16th of August and ends on the 31st of December. In 1998, 98 sites were allocated all around the island except for a corridor for swordfish and tuna longline fishery, as indicated on figure 3. The sites start from 7 miles offshore at intervals of a half or three quarters of a mile depending on the district (Potoschi & Sturiale, 1996). The largest number of fishing sites allotted was 140, but along the years, some fishermen started opting to target other commercial species and, as a consequence, the number of applications for "lampuki" fishing has dwindled to 86 in 1999 (Bussuttil, pers. comm.).

Each boat uses a minimum of 35 FADs (kannizzata) at visible distance from each other along routes called "rimja" (fig. 3) (Farrugia-Randon, 1995). Since mechanisation of the fleet, the number of FADs deployed by boat has increased notably from 20 to a mean of 35, although the larger boats may lay much more FADs (200 sometimes) along the fishing site (Bussuttil, pers. com.).

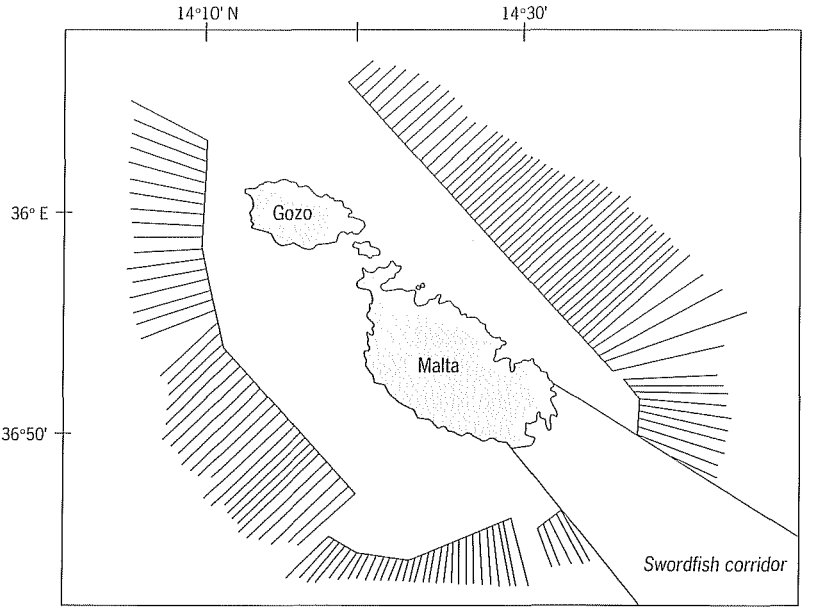


Figure 3
Mooring areas off Malta (from Farrugia-Randon, 1995).

The dolphinfish are caught by surrounding nets similar to purse seines but without the purse rings (Galea, 1961). The size of the nets depends of the size of the operating boat, but the overall length appears generally to measure about 210 metres. When the boat is near a FAD, various trolls made out of feathers or artificial bait are set and when one fish is caught, a decoy dolphinfish is thrown into the sea to attract any others that may be present under the FAD. When the number of fish present makes it worthwhile, the surrounding operation is then undertaken. Other dolphinfish fishing methods include trolling (catching the fish with a moving lure) and surface longline (Farrugia-Randon, 1995).

Tunisia

Dolphinfish fishery is carried out along the whole Tunisian coast (fig. 4), and constitutes an important resource for the small-scale fleet. The main fishing areas are concentrated around Cape Bone (off the Beni-Khiar port), in the Sahel (around the Mahdia port), and in the most southern area (around the Zarziz port). Like in other areas of the Mediterranean (Galea, 1961; Massutí & Morales-Nin, 1991), this fishery is seasonal, extending from the second fortnight of August to early December (Vella, 1999).

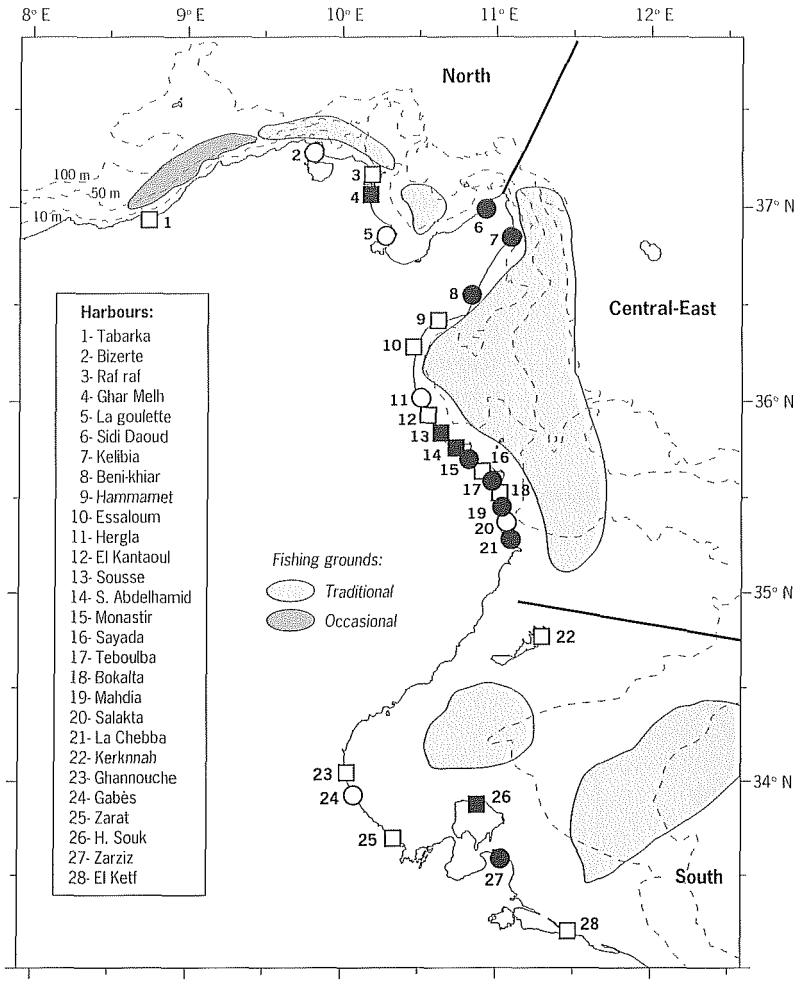


Figure 4
Mooring areas, fishing ports and landings by port in Tunisia (from Zaouali & Missaouri, 1999).

A total of 260 fishing boats from 20 harbours are directed to this fishery (fig. 4). The major part (72%) is concentrated along the central-eastern coast (around 30 boats in each port), while the rest is distributed along the northern (10%, 20 boats per port) and the southern coast (18%, 30 boats per port). In this last area, there is a marked tendency for an increasing effort (Vella, 1999).

In average, the boats are 11 m length, and propelled by 45 HP motors. In some ports as Monastir, they are equipped with a winch to haul the net. Five fishermen are aboard.

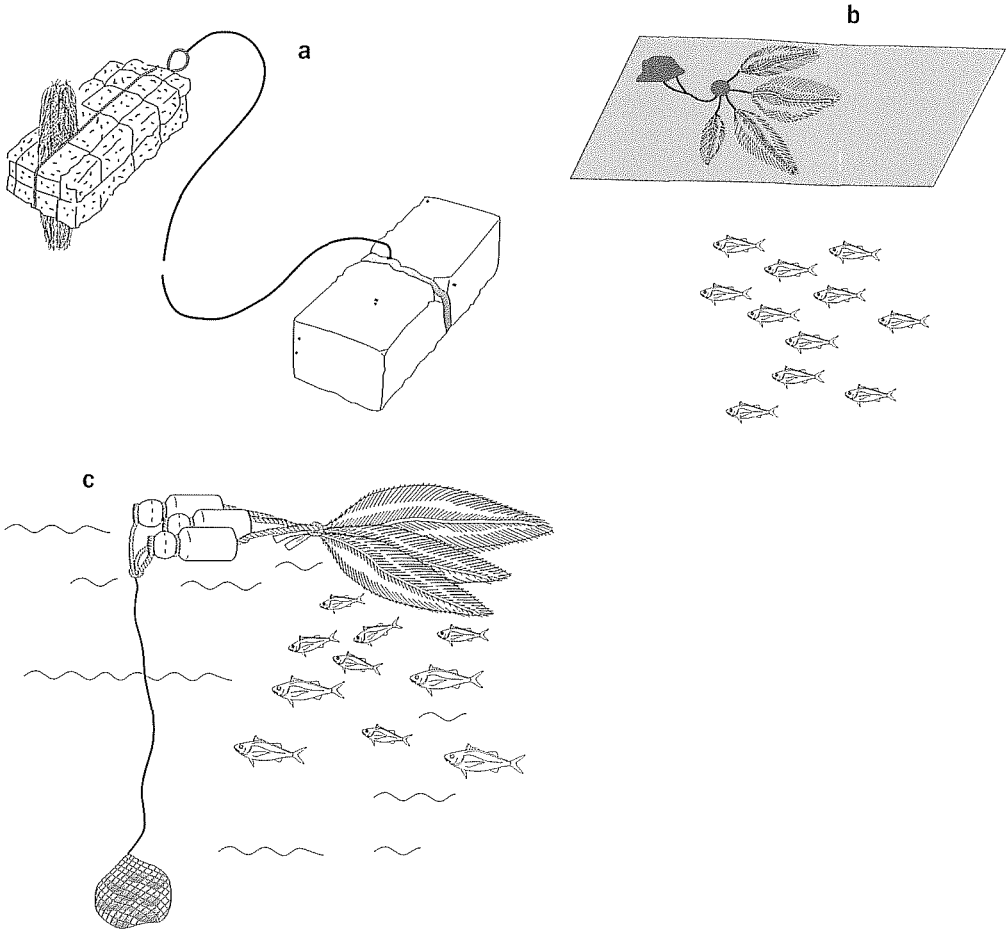
Each boat uses between 17 and 75 FADs during the whole fishing season. They are grouped in rows, with an interval of about 50-80 m between two FADs, the first one having a mark so as to recognize its owner from a certain distance. Each group has the name of the boat and an order number showing its place at sea (generally referred to GPS). The FADs are mainly anchored in areas from 30 to 60 m depth, although in some ports of the southern coast they can reach 180-m depth and around 60 miles off the coast (Vella, 1999).

The gear used is a surrounding net without purse line (called "lamboukara"), 200-300 m long and 15-35 m high made of high-density polyamide monofilament. Fishing operations are carried out at sunrise, and the dolphinfish schools detection is made by observing the birds flying around FADs, the movement of the water surface, or by trolling line (Vella, 1999).

FADs

The traditional FAD used in Malta (cima), Majorca (capcer) and Sicily (cannizzi) consists of a cork float with some palm fronds or bush branches tied on top for location and below to increase their surface. The composition and form of the FAD may vary from the traditional cork to a group of tyres, being the material selected for its characteristic of floating just below the surface and its cheap price. The entire FAD is moored to an anchor typically made of one or more large stones or anchor blocks. Drifting FADs are occasionally used (fig. 5).

Figure 5
FADs used in the Mediterranean.
a) Malta and Majorca;
b) Drifting FADs;
c) Tyrrhenian Sea
(from Massutí & Morales-Nin, 1991; Potoschi & Sturiale, 1996).



The most common Fish Aggregating Device (FAD) used in Tunisia is the "ghanatsi" or "jrid". It has a trapezoidal or V-shaped wooden frame, about one metre long, 20 cm in the highest part and 60 cm in the widest one. Some palm leaves are disposed in the middle (Massutí *et al.*, 1999). In some cases, plastic sheets may replace these palms. Each unit has a rope with a ring attached to the ballast (a concrete block of 20-70 kg) in one end, and to some floaters (usually 5-litre empty plastic bottles) in the other. There is a simplified version, called "chefchaa", used in Cape Bone, which is made only with three fan-like disposed palm leaves, with the spines covered by plastic in order to protect the net (Vella, 1999).

Catch data

Majorca Island

A historic data series for the annual landings from 1981 to 1996 inclusive, shows wide fluctuations, from two metric tons to more than 120 mt, with a mean of 63, a standard deviation of 35, and a slightly increasing trend (4 tons per year, $r^2 = 0.3$) (fig. 6). The 10-year historic monthly data series of catches from 1987 to 1996 fishing seasons shows the concentration of the main catches in September-October. The effort data for this period shows that the fleet has remained stable at around 50 boats.

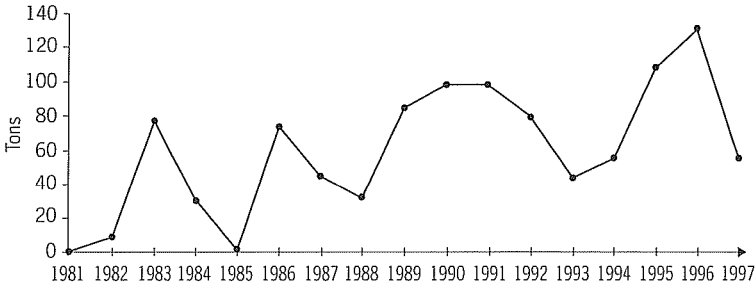


Figure 6
Landings in Majorca. Annual time series from 1981 to 1997.

Sicily Island

The catch data of dolphinfish for 1996 is shown in figure 7. The values included show that out of a total of 377.4 tons caught in Sicily, the highest value correspond to October, where the 158 tons represent 41,86% of the total catches for the 1996 fishing season. In these catches, 22.29 tons are landed by boats of Termini Imerese and Porticello which fish by sighting the shoals which gather under the drifting floating devices. This represents 5.9% of the catches made with FADs.

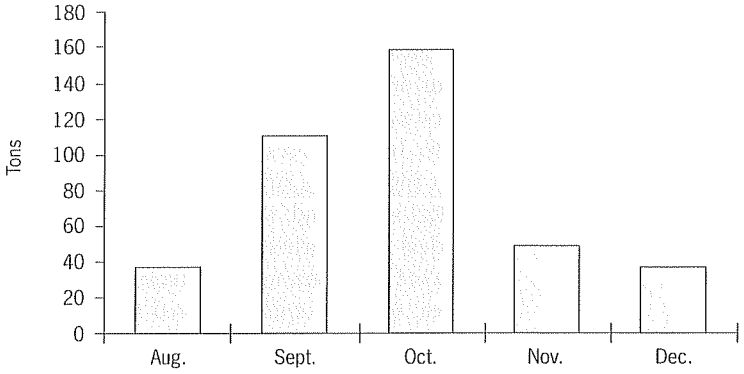


Figure 7
Monthly landings (in tons) in Sicily for 1996.

Malta Island

The annual landings of dolphinfish since 1980 are illustrated in figure 8 (Potaschi & Sturiale, 1996). These statistics show a seasonal peak in dolphinfish landings between September and October and a longer fishing period than in other areas with catches on January (2%).

Figure 8
Annual time series of Malta landings (in tons) from 1980 to 1998 (data from Bussuttil, pers. comm.).

The fishing effort has decreased (169 fishing licenses and sites in 1985 to 96 in 1998) due to the dedication for more profitable fisheries such as swordfish and tuna, which have developed recently (Farrugia-Randon, 1995; Vella, 1999).

Tunisia

Year landings of dolphinfish in Tunisia have increased progressively during the two last decades, following the increase on fishing effort observed in the fishery (Massutí *et al.*, 1999). From 1990 to 1997, they ranged between 125 tons in 1992 and 417 tons in 1995 (fig. 9a), with an average yield around 300 tons. The monthly distribution of the catches (fig. 9b) shows the seasonality of the fishery (from August to December), with the bulk of landings (>70%) in September-October (Vella, 1999).

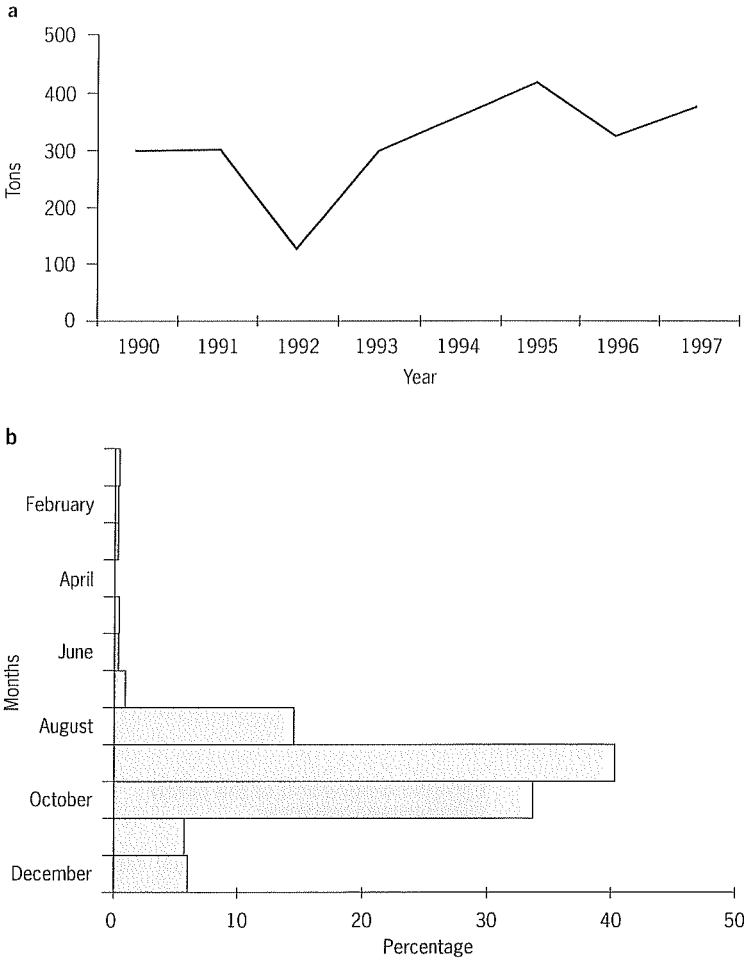


Figure 9
Landings in Tunisia.
a) annual time series from 1990 to 1997.
b) mean monthly catch (from Zaouali & Missaouri, 1999).

By-catches

Together with the dolphinfish, pilotfish and amberjack are also captured as by-catches, but in much smaller quantities. In Majorca, the amberjack registered landings on the Central Wharf are overestimated due to the fishermen practice of rearing the live juveniles and selling them later with better mean weights. The pilotfish landings in Majorca show great interannual variations with values ranging from 0.9 to 30.5 metric tons (fig.10a). The time series of the landings for Malta show the same variability for pilotfish and amberjack (fig.10b), which represented 3.6% and 1.6%, respectively, of 1998 landings of dolphinfish fishery (Bussuttil, pers. comm.).

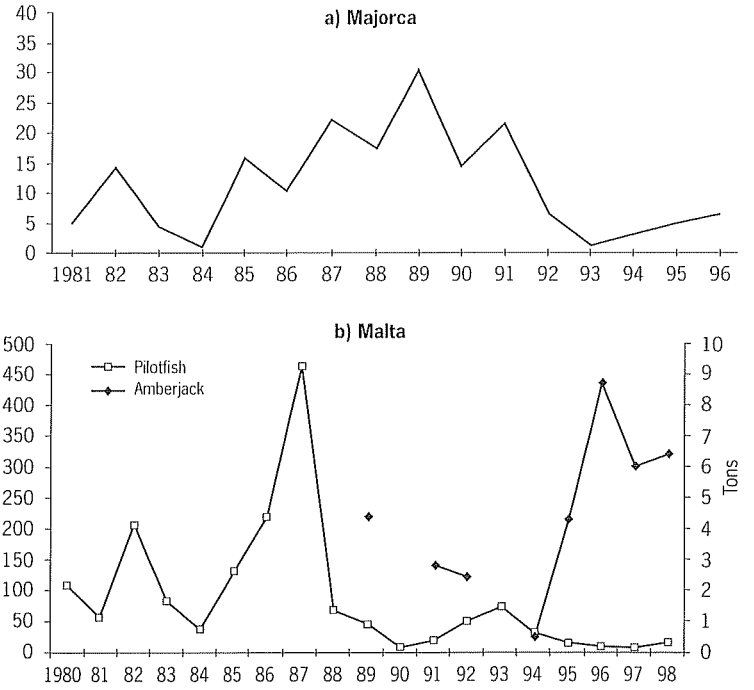


Figure 10
By-catch of dolphinfish fishery.
a) Majorca pilotfish landings;
b) Malta pilotfish and amberjack landings (Malta data from Bussuttil, pers. comm.).

Length composition of the catch

The length composition of the catches in Majorca Island range from 20 to 64 cm fork length in 1995 and from 23 to 64 cm in 1996. In both years, the mean monthly length increased through the five-month sampling period. The length composition showed 2-3 modes per month, including a mode of small fish at the end of October and November 1995 (fig 11). The length composition of the catch in Sicily was comprised between 20 and 60 cm fork length. The dolphinfish fast growth rate appears clearly in these length compositions when the modal length evolution by fortnight is considered.

Sicily fishery economic analysis

Methods

In the 1996 dolphinfish fishing season with FADs and purse seine all the boats dedicated to this activity in Sicily and in the Pelagic Archipelago were counted in a census. In 5 sample ports (Lampedusa, Linosa, Trapani, Sant'Agata di Militello and Siracusa) catches and the fishing effort were taken through interviews during landing, based on samples in time and space or based on a census. In addition, average prices per week paid to fishermen were taken through direct observation, as well as boat running costs by interviewing shipowners. In 4 of the 5 sample ports (Linosa, Lampedusa, Siracusa and Sant'Agata di Militello) the

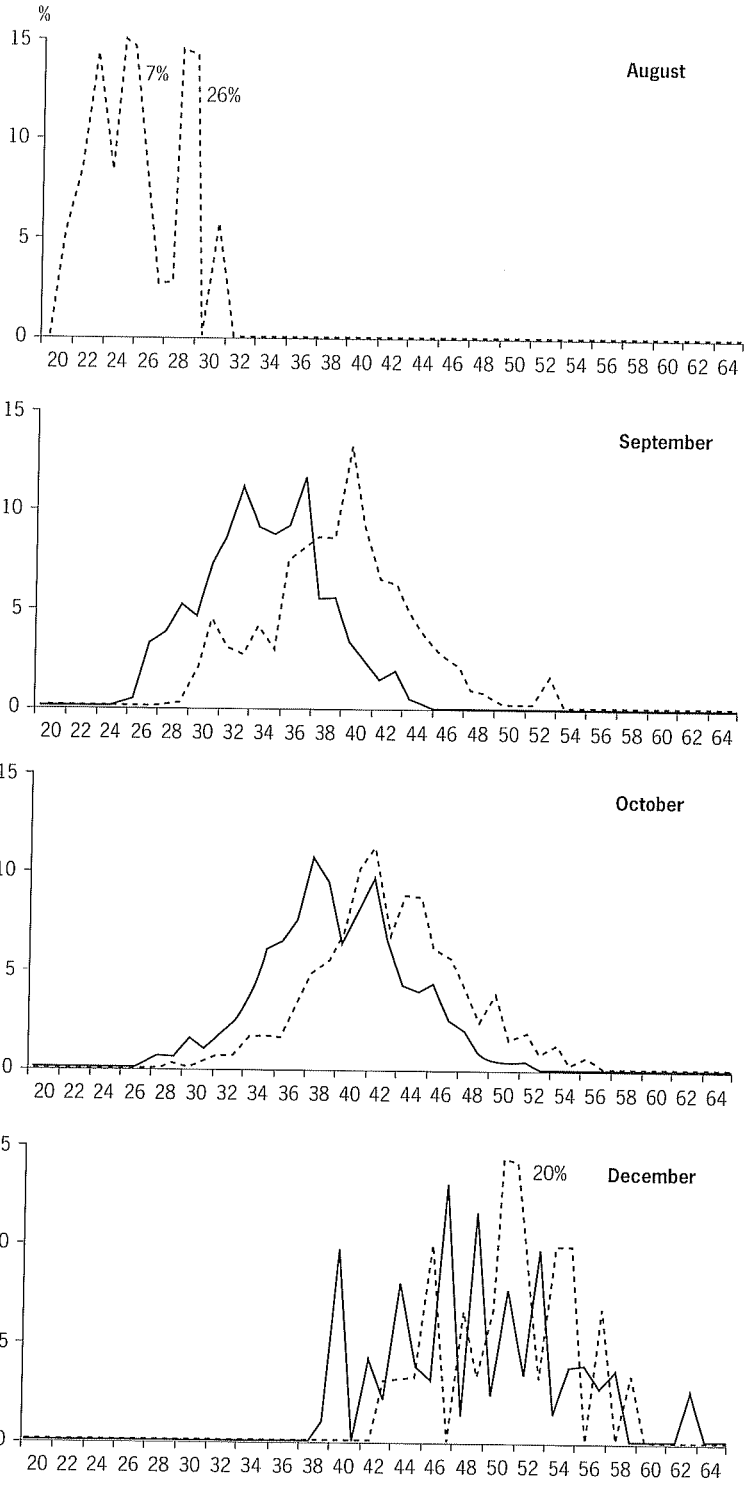


Figure 11
Evolution of the monthly length composition of the catch in Majorca for 1995. Continuous line: 1st fortnight; dotted line: 2nd fortnight.

surveys were carried out through a census in space and time; in practice, it is by interviewing all the fishermen every fishing day, except in Trapani where the surveys were carried out through sampling in space and time, that is most of the fishermen being interviewed three times a week (Mondays, Wednesdays and Fridays).
Costs have been gathered in four categories:
- **Running costs:** fuel, oil, ice, spare parts and repairs;
- **Cost of fishing gear** concerning the whole cost of the FADs;
- **Cost of capital** including depreciation and opportunity costs;
- **Labour cost** estimated according to the cost principle opportunity.

Repairs include both ordinary and special maintenance changes. The term "capital" means the value of the boat, inclusive of gear and facilities. The opportunity cost of capital has been calculated by assuming that the capital stock value of the fleet would be invested in treasury bonds only during the months dedicated to the dolphinfish fishing (1 September 1996-31 December 1996). This principle has been also used to estimate the labour cost on the basis of the following reasons: the Italian system adopted by the fisheries to pay crew members is said to be "on a lay". With this system, the net revenue (gross revenue less some running expenses) represents the whole revenue which is divided fifty-fifty between the shipowner and crew members. It's clear that this system has some difficulties in checking salaries. So we have assumed that fishermen could be alternatively employed in the agriculture sector and we have estimated the daily salary for a fisherman with the daily salary of a farm-hand. On the basis of that principle, we believe that an average monthly salary is underestimated in comparison to the one actually received through the system of being "on a lay". The revenues have been estimated by multiplying weekly catches and prices. The economic rent has been estimated by the difference between revenues and costs. Prices, costs, revenues and economic rents have been estimated in Ecus (1 Ecu ≅ US$ 1.1).

Cost analysis

In the Pelagic Islands of Linosa and Lampedusa, the prices of dolphinfish are generally lower than in the most important ports of Sicily, for two reasons: lack of an internal market and transport costs. They are fixed through negotiations between fishermen and wholesalers. Linosa and Lampedusa fishermen sell the majority of the catch to a local warehouse with whom they have a privileged relation, which in turn carry the fish by ferry to Sicily, where it is distributed by Porto Empedocle, Catania and Palermo wholesalers. A small quantity of catch is usually sold locally. In 1996 in Lampedusa, wholesale prices were steady during the fishing season, because fishermen fixed them at the beginning of the season, in agreement with the wholesalers. In Linosa, the wholesale price was 2.1 Ecus until 10 September and 1.5 Ecu for the remaining part of the season. By the middle of November, it is no longer convenient for dealers to pay dolphinfish at 2.1 Ecus per

kilogramme, as at the beginning of the season. Therefore, the fishermen from Lampedusa were forced to stop fishing. In 1996, the average wholesale price for dolphinfish varied in the most important ports of Sicily, from a minimum of 3.0 Ecus to a maximum of 6.2 Ecus in Siracusa. In Siracusa and in Sant'Agata the wholesale prices are higher than in the other analysed ports, because in Eastern Sicily the dolphinfish demand is much higher. In Siracusa, the average wholesale price was about 5.2 Ecus with a maximum of 6.25 Ecus and with the minimum being 4.15 Ecus. In Sant'Agata and Trapani, the average wholesale prices were respectively of about 4.18 Ecus and 3.55 Ecus.
The highest prices were at the beginning of the fishing season because of a strong demand, subsequently there was a decrease. Generally the interaction between demand and offer gives rise to small price fluctuations.
• From the analysis of the total costs registered by the fleets dedicated to the dolphinfish fishing it is deduced that labour costs have a greater impact than any other costs do. On average, it affects the total costs by 33 per cent. The minimum impact is recorded in Trapani, whose fleet is composed of small boats which require 2 or 3 fishermen at most, whereas the greatest impact (34%) is recorded in Linosa, Sant'Agata and Siracusa; nevertherless, in Linosa the large impact of labour cost is not connected to the structure of the fleet, which is also characterized by small size boats, but rather to the small impact of other costs.
• Running costs (Siracusa, Lampedusa, and Trapani) or the cost of the fishing gear (Sant'Agata, Linosa), after labour costs, have a less impact with fewer percentage points. As far as running costs are concerned, fuel consumption cost is the common feature for all the fleets under consideration, being the highest share. It affects running costs at a level of 72% on average, varying from a minimum of 60% in Linosa and a maximum of 81% in Siracusa, depending on the amount of hours spent at sea and of the structural features of the fleet.
In Linosa and Lampedusa, running costs have been noticed lower than in the other ports because of the small size of the boats, the closeness of fishing areas and the higher repair costs.
Maintenance charges have little impact on running costs. They vary between a minimum of 14% in Siracusa and a maximum of 36% in Linosa.
• The cost of FADs has an average impact of 23% on the total cost. It is not a fixed cost being a disposable tool, which means that it is completely exploited for only one fishing season. The total cost depends on the number of boats and on the number of "kannizzi" at sea, referring to the entire fleet dedicated to dolphinfish fishing. In 1996, each boat lowered an average of 48 FADs with an average cost of 36.3 Ecus per "kannizzi". Sant'Agata fleet has moored the greatest number of FADs, about 65 per boat on average.
• The capital cost, whose average impact is 20% of the total costs, has been subdivided into depreciation and opportunity costs. Since all the boats employed in the dolphinfish fishing are older than 10 years, they

are completely depreciated and so the depreciation is referred to gear purchased during previous years. The average net rate of the Treasury Bonds in the period 1 September 1996-31 December 1996 was 5.86% and the opportunity cost of the capital has been calculated by assuming that the capital stock value of the fleet would be invested in State Bonds (Treasury Bonds) in the previously period and rate. The opportunity cost varies from a minimum of 1.214 Ecu in Lampedusa (where only 2 boats practise dolphinfish fishing) to a maximum of 15,668 Ecus in Siracusa. If we compare the value of the opportunity cost with the value of the yield, it is clear that investing in fishing dolphinfish is more profitable than investing in State Bonds. For example, in Sant'Agata the yield is equal to 94,973 Ecus, instead the opportunity cost is equal to 11,224 Ecus.

Analysis per port

In 1996, in the islands of Linosa and Lampedusa, the good results obtained in the previous season convinced the owners of the boats practising dolphinfish fishing to purchase new gear and to moore a greater number of "kannizzi". Two new boats were induced to practise this kind of fishing, attracted by the prospect of gaining high incomes. However, the gross incomes gained in that season were not as expected. As a matter of fact, in Lampedusa the total income was 9,797 Ecus, whereas the highest income was reported in Linosa with 56,458 Ecus. In both islands, since the price was, more or less, constant (only in Linosa there was a fluctuation from 2.07 Ecus to 1.55 Ecu from the first to the second half of October) the state of the incomes was in relation with the catches. In Linosa, the highest incomes were gained in the second half of November and were equal to 12,227 Ecus, whereas in Lampedusa they were only of 3,237 Ecus (equal to 26%).

In Trapani, Sant'Agata and Siracusa the total incomes were higher: 69,970, 222,382 and 463,196 Ecus, respectively. In those ports, the price was not constant, although the interacting of demand and offer caused some small price fluctuations, so that the state of the incomes was mostly influenced by the trend of the catches. From the analysis of the incomes in time, it appears that in three ports (Linosa, Sant'Agata and Trapani), the highest income was gained in October, as a result of the greater quantity of fish caught in comparison to the other months. The yield is equal to the difference between the total income and the total costs. Among the five ports under consideration (tab. 1), it turns out that the yield, as percentage of the total income, varies from a minimum of 10% in Lampedusa to a maximum of 46% in Linosa. In 1996, in Lampedusa the fishing of dolphinfish was not very profitable as a result of the fall of catches in comparison to the previous season.

In the other ports, this activity shows a good yield, although it is to be considered inclusive of tax. The good results obtained in Linosa are owed to both catches (they represent 33% more of those ones obtained by an equal number of boats in Trapani) and mostly the impact of the

total costs on total incomes, which show the lowest value (54%) in comparison to those observed among the other ports. Whereas in Linosa and Lampedusa the fishing of dolphinfish is a relatively new business, it is instead an ancient tradition among the other ports under consideration. In particular, in Sant'Agata and Siracusa, such activity has significant importance from an economic point of view. As a matter of fact, prices are usually higher there and the boats employed in the fishing of the dolphinfish are more numerous and longer. Only in those two ports the total catches are about 70 per cent. However, in Siracusa, even though catches were abundant, the high impact of the total costs on the total income (70 per cent) owed to the fleet structure, eroded the yield that was equal to 30 per cent. In Sant'Agata and Trapani, the yield was 43% and 39%, respectively.

Table 1 - Economic aspects on some Sicilian dolphinfish ports. a) Total costs. b) Running costs. c) Economic rent (from Cannizzaro *et al.* 1999).

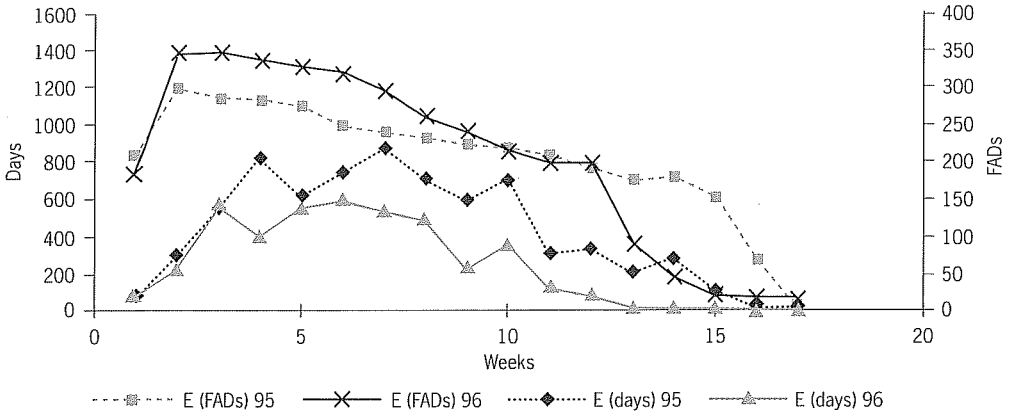
a	Lampedusa	Linosa	Trapani	Sant'Agata	Siracusa
Running costs	27%	14 %	27 %	20 %	31 %
Cost of fishing gear	18%	29 %	23 %	31 %	18 %
Labour costs	32%	34 %	30 %	34 %	34 %
Cost of Capital	23%	23 %	20 %	15 %	17 %
Total costs	100%	100 %	100 %	100 %	100 %
b	Lampedusa	Linosa	Trapani	Sant'Agata	Siracusa
Fuel costs	69%	60 %	75 %	75 %	81 %
Oil costs	4%	4 %	5 %	5 %	5 %
Repairs	27%	36 %	20 %	20 %	14 %
Running costs	100%	100 %	100 %	100 %	100 %
c	Lampedusa	Linosa	Trapani	Sant'Agata	Siracusa
Running costs	25%	7 %	17 %	12 %	22 %
Cost of fishing gear	16%	15 %	14 %	18 %	13 %
Labour costs	28%	18 %	18 %	19 %	23 %
Cost of Capital	21%	13 %	12 %	8 %	12 %
Total costs	90%	54 %	61 %	57 %	70 %
Economic Rent	10%	46 %	39 %	43 %	30 %
Gross Revenue	100%	100 %	100 %	100 %	100 %

We can finally say that, except Lampedusa in which the fishing season has not given interesting results (Cannizzaro *et al.*, 1996, 1997, 1999), dolphinfish can be considered in Sicily as a species which gives good profits, assuring one of the highest economic rent rate (from 30% to 46%) in the fishery market from September to December. At the moment, dolphinfish is only freshly-marketed, within the EC countries, in Sicily and in the Balearic Islands (Morales-Nin *et al.*, 1995; Missaoui & Chakroun, 1997). Probably a price rise caused by an increase in demand, which it might happen if the dolphinfish market would be expanded both freshly and preserved in the other European countries, could persuade other fishermen to catch dolphinfish instead of other overexploited species, as for example swordfish between August and December (Cannizzaro *et al.*, 1996, 1997, 1999).

Population evaluation in Majorca

Measuring dolphinfish fishery effort is not easy, due to the aggregatory behaviour of the species and the nature of the fishing operations. The number of FADs, hours fishing and fishing days in 1995 and 1996 have been collected by means of log books distributed to the fishermen (Morales-Nin *et al.*, 1995; Missaoui & Chakroun, 1997). After some previous analysis, the mean number of FADs and fishing days per week have been used as a measure of the effort. The evolution along the fishing season shows a sharp increase at the beginning of the season and a slow decrease at its end (fig. 12). In 1996, due to the bad weather, the effort was lower because of the impracticability of the fishing method in rough sea conditions and to the loss of FADs.

Figure 12
Effort along the fishing season on Majorca for 1995 and 1996 measured in fishing days and FADs number (from Lleonart *et al.*, 1999).

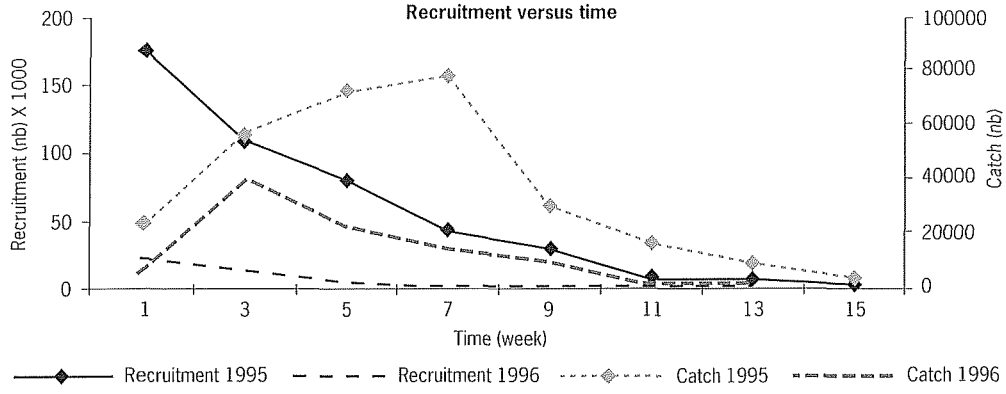


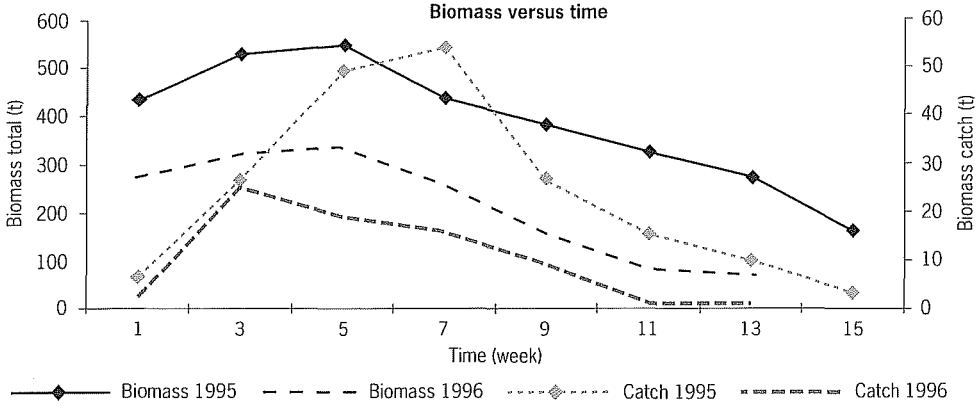
A VPA analysis with the week as the time unit was carried out by Lleonart *et al.* (1999) based on weekly catch data for 1995 and 1996 and dolphinfish biological parameters. The time series of landings and effort and the results of the 1995-1996 study, showed marked fluctuations in catch and abundance. Since fishing exploits juvenile age-0 fish, it is reasonable to expect the combined effects of recruitment variability, and accessibility of recruits to the fishing grounds/fishing gear, to give rise to significant differences.

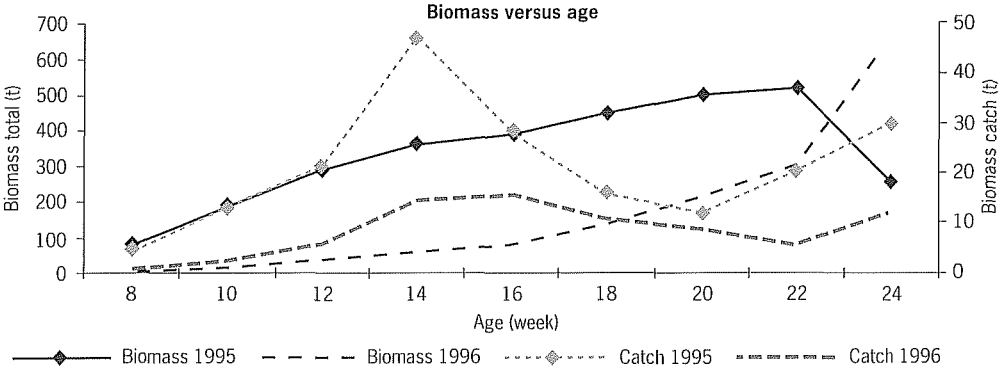
The reported steady increase of dolphinfish catches in other areas (Caddy, 1990) is also found in Majorca. Although the trend is obscured by the strong periodic fluctuations observed. The trend should be independent of an increase in effort, because the number of boats has remained constant since 1984 and the gear and fishing operations are traditionally the same. The fluctuations might be due both to failures of the annual spawning of the species in Mediterranean waters, and/or to the recruitment of the species and also to the fishery (fig. 13). In the Mediterranean, and other subtropical fish populations, where the first-year classes are intensively exploited and where annual catch fluctuations are observed, the ulti-

mate explanation must be sought in the underlying environmental factors. They control the "recruitment windows" and are more relevant that the existence of large or small spawning peaks (Morales-Nin *et al.*, 1999).

Figure 13
VPA analysis on the dolphinfish population of Majorca for 1995 and 1996 (from Lleonart *et al.*, 1999).







In order to evaluate the fishery impact upon the dolphinfish population mortality, several issues should be considered. Some of them depend upon the fishery itself, such as the small boat size, the characteristics of the net and fishing operations, and the distance of the fishing areas from coast. All made the fishery very sensitive to bad weather. In 1996, the amount of fishing days decreased sharply due to very bad sea conditions on November-December (Iglesias *et al.*, 1995; Morales-Nin *et al.*, 1995). The dolphinfish biology and distribution are also very relevant. For instance, the decrease of captures due to bad weather in 1996 should also depend upon the fish distribution in relation to land. Probably during bad weather the fish remain further offshore.
Other important biological characteristics are: 1) the exploited fraction of the population is composed of 0-age class fish originated in the area with very fast growth rates; 2) dolphinfish is very mobile and may enter and leave the fishing area many times during the fishing season; 3) it is a migratory fish which will depart when the water temperature decreases and when it reaches an adequate size for migration. These characteristics have importance for the real value of M, but are difficult to quantify.
More precise evaluation models should consider the size of the population not attracted by the FADs, the rate of arrival of fish to the FADs and the time of residence. However, in the management of the fishery, the socio-economic aspects and the market have to be considered as management options.

Conclusion

In the Mediterranean, the dolphinfish catches have increased in recent years (Caddy, 1990). This fishery is a traditional activity with at least 100-year duration in Majorca although this fish is mentioned since the 14th century (Massutí & Morales-Nin, 1997). In this island effort, as number of boats, has remained constant in the last 15 years. The relative importance of this fishery during the 5-month fishing period, ranges from 6.2% of the fleet engaged in Malta to 45% in Majorca. However, in Sicilian Seas, dolphinfish has been fished for many years, but the fishing areas were limited and the fleet engaged in this activity was small. In recent years, there has been an increase of the number of boats with a consequent expansion in the areas for positioning the FADs which from the southern Ionian Sea has extended to the northern part, the southern Tyrrhenian Sea and West Sicily. This increase is also notable in Tunisian waters, while in Malta the effort directed to this fishery has decreased from 169 boats in 1985 to 96 in 1997. From the total of 1,206 metric tons captured in 1996, 35% correspond to Tunisia, 31% to Sicily, 24% to Malta and 11% to Majorca. These landings correspond to the effort directed to the fishery, in number of boats as well as in number of FADs deployed (tab. 2).

Table 2 - Summary of the available data on boats and gears used in the dolphinfish Mediterranean fisheries.

Area	Nb of boats	Crew	Mean length	GRT	HP	Total nb FADs	Nb FADs/boat	Depth (m)	Net size (m)
Majorca	36	2 (4)	8.3	5.6	64	1156	30-40	70-1200	180x16
Sicily	225	2-4	11.01	10.12	122	21920	10-110	<800	180-216x45-72
Malta	111	5-8	>6<15	-	-	15000	>35	-	175x10
Tunisia	260	5	11	-	45	27300	17-75	30-180	200-300x15-35

The catch systems used have not undergone substantial technological changes compared to the equipment of the past. Over recent years, the conviction has prevailed among Sicilian fishermen that by increasing the decoy factor (number of FADs), the catches must increase proportionally. This may be considered when historical series of catch and effort are available. A strong interannual fluctuation occurs in all areas, which might be similar to the general decrease of landings in 1992, or fluctuate independently. This variability is linked without doubt to environmental factors related to ethological and biological aspects of the species, whose presence in Mediterranean waters records scheduled periods of disappearance.

Although dolphinfish offer a good economic revenue, the marked and the distribution channels limit the exploitation. However, the population analyses have shown that the fishery is based upon the annual recruitment. This warns off the enormous impact of possible recruitment failures in the population. These possible failures could explain the falls of the catches registered during some years. These recruitment failures could be due, among others, to changes in environmental parameters and their effect in the recruitment pattern. Nevertheless, we cannot rule out other causes, such as resource availability due to modifications in the behaviour pattern, which also constitutes a failure of recruitment to the fishery; the ultimate cause being changes in the environmental parameters. Therefore, this indicates the necessity to intensify the studies directed towards determining the environmental influences on the population dynamics.

Acknowledgements

This paper is a result of DG XIV EU Biological Study projects 94/31 and 95/73. Dr C. Bussuttil (FAO, CPEMED, Malta) is thanked for kindly providing Maltese data.

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