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BIOLOGY AND FISHERY OF DOLPHINFISH AND RELATED SPECIES. *E. MASSUTÍ and B. MORALES-NIN (eds.)*

Population dynamics and fishery of dolphinfish (*Coryphaena hippurus*) in the western Mediterranean*

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SUMMARY: The dolphinfish (*Coryphaena hippurus*) fishery based on the island of Mallorca (western Mediterranean) and the population dynamics of the species were studied between 1995 and 1996. Fishing effort, landings and length composition of the catches during the sampling period, as well as the historic catch data series and fleet were analysed. Virtual Population Analysis (VPA), taking as the time unit the week in 1995 and the fortnight in 1996, were also carried out. Dolphinfish is fished from August to December, with main catches in September-October, using anchored fish aggregation devices (FADs) and surrounding net. The mooring areas, placed from 70 to 1200 m depth, are distributed among the boats registered for the year's fishery. A total of 46 boats took part in this fishery in 1995 and 37 in 1996, with a catch of 128 and 52 metric tons respectively. These wide fluctuations are also shown in the annual catches of the 16year series, which ranged from 2 to more than 120 metric tons, showing a slightly increasing trend (4 tons per year). The comparison of different measures of effort (FADs, days and hours) showed similar values of CPUE, although the number of FADs showed the lowest variation, with normal variances and average values not significantly different between harbours. The length composition of the catches ranged from 20 to 64 cm fork length, which corresponds to juveniles between 2 and 6 months of age. The main results of the VPA, which must be regarded in relative rather than absolute values, showed that the available population and the recruitment in 1995 are greater (around one order of magnitude) than in 1996. For both years, the number of individuals declined in the course of the fishing season, while biomass increased during the first 5 weeks. The fact that the exploited fraction of the dolphinfish population is composed of 0-age class suggests that catch fluctuations might be related to environmental parameters and to the migratory behaviour pattern of the species. These two interrelated factors can produce failures of its annual spawning in the western Mediterranean, and/or of the recruitment of the species to the fishery.

Key words: Coryphaena hippurus, fishery, FADs, VPA

INTRODUCTION

Mediterranean small-scale fishing is a variable activity with highly multispecific catches with fishing intensities and strategies showing very rapid fluctuations in space and time. The seasonal activity of the fleets is related to the ecology of the different species, meteorological conditions, the tourist season, etc. In order to quantitatively assess 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 evaluation of total production and fishing effort, which are of paramount interest for the studies of fisheries and exploited resource dynamics (Farrugio and Le Corre, 1993).

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In Majorca (Balearic Islands, western Mediterranean), around 45% of the small-scale fleet is engaged in three main seasonal fisheries directed at *Aphia minuta* from December to March, *Palinurus elephas* from March to August, and *Coryphaena hippurus* from August to December. Other small-scale fisheries at the island are directed at 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 (Iglesias *et al*., 1995).

The dolphinfish (*Coryphaena hippurus*) fishery uses traditional fish agregation devices (FADs) to increase the availability of this migratory oceanic fish resource through the creation of productive target fishing locations. The gear for dolphinfish is a special surrounding purse net without a purseline called "llampuguera" (from "llampuga" the Catalan name of the dolphinfish). Its average size is 180 m in length and 16 m in depth (Massutí *et al*., 1999).

The catches are composed of juvenile 0-age fish that have been spawned in late spring and early summer (peak spawning in June-July) and will leave the zone at the beginning of winter (Massutí and Morales-Nin, 1995). Dolphinfish reproductive patterns, feeding and age and growth have been studied in the area by Massutí and Morales-Nin (1995, 1997) and by Massutí *et al*. (1998, 1999). However, no previous evaluation or assessment of this stock has been made. Only Massutí and Morales-Nin (1991) and Iglesias *et al*. (1995) have described the fishing methods, the dolphinfish length distribution of the catches and landings.

This paper presents the historic catch data series and the results of a two-year sampling programme of the Majorcan small-scale dolphinfish fishery. A virtual population analysis method (VPA), modified to use the week as the time unit, has been used to evaluate the dolphinfish stock.

MATERIAL AND METHODS

Fleet and gear characteristics

The fishing ports, FADs 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 were small, with 8.3 m mean length, 5.6 GRT displacement and 64.0 hp engine power. Except in Port de Sóller, all the boats had one or two hydraulic net winches. They are manned by the fishing master (generally the owner) and 1-2 fishermen, except in the Port de Sóller where the average crew is 4-5. The number of boats per port is around eight, except in Palma where there are only three and Port d´Andratx where they are four.

Dolphinfish is fished using anchored FADs (Fish Aggregation Devices). The FAD consists of a cork float with some palm fronds or bush branches tied on top for location and below to increase their surface (Massutí and Morales-Nin, 1991). The composition and form of the FAD varies from the traditional cork to a group of tires, which is selected for its characteristic of floating just below the surface. It is moored using a limestone anchor.

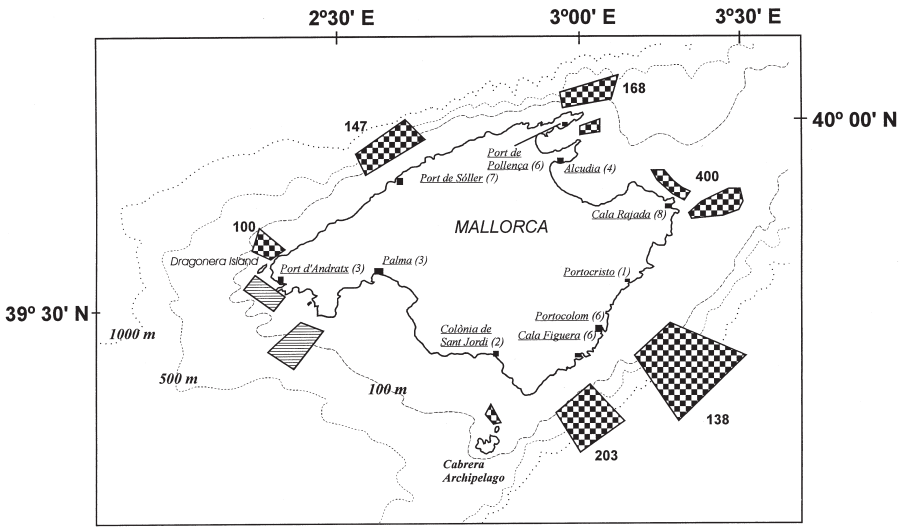

FIG. 1. – Dolphinfish fishing ports on Mallorca Island, with sampling ports underlined. The traditional FAD mooring areas corresponding to each port are indicated, as well as the number of FADs by area. Lighter shading indicates mooring areas that are not actually used.

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 30-40 FADs at its mooring location, except Port de Sóller with 20-28 FADs/boat. This port is exceptional because after fishing in the mooring areas they spend most of the time looking for floating debris and fishing around it.

The mooring areas of each port are located at depths greater than 70 m and may be as deep as 1200 m. All harbours have one mooring area per boat (Fig. 1), except Port de Pollença 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 long-line fishery for swordfish (*Xiphias gladius*) (areas with lighter shadowing, Fig. 1). Palma vessels moor FADs in a small area west of Cabrera Archipielago. Thus, due to the proximity to the Colònia de Sant Jordi port, this fleet changes its base there seasonally.

The number of FADs lost due to bad weather or due to long-line activities was high in both years, reaching 76.2% of the total FADs on average. The fishermen replaced the FADs several times during the fishing season with the consequent variation of effort.

Catch data

Two historic data series were available: a) 16 years, from 1981 to 1996 inclusive, of annual landings of the dolphinfish fishery on the Island; and b) 10 years, from 1987 to 1996 inclusive, of the monthly dolphinfish landings of 10 harbours, and the number of boats registered to fish dolphinfish in each port by year. These data series were obtained from the registers of the fish market at the harbour of Palma.

The 10 years of data were examined by a correspondence analysis of the capture per unit effort (CPUE), calculated as the monthly landings of each port divided by the number of boats registered for the fishery for the year and the port. The data comprised 9 harbours and 40 observations.

Sampling

A frame survey census was carried out in the 1995 fishing season covering all the fishing harbours of Majorca. This involved listing all the fishing boats according to their port or unloading location, using data from port authorities. The fishing masters or boat owners were interviewed for boat characteristics and fishing operations. Based on these data, a regular time sampling strategy was chosen (Scherrer, 1983). The six main harbours were selected (Fig. 1) and visited fortnightly during the 1995 and 1996 fishing seasons (August-December). Observers went on board during the fishing operations to sample the length frequency composition of the catch.

Daily landings during the fishing season by boat were obtained from the fish market at the harbour of Palma. To obtain a measure of the effort, questionnaires were distributed among fishermen of the selected harbours. Information on the boat characteristics, location and number of FADs, number of hauls per day, fishing days, and catch of the day was sought. In 1996 the number of hours per day committed to the fishery was also included. A total of 27 and 31 questionnaires were distributed in the 1995 and 1996 fishing seasons respectively. They represented 58.7% and 79.7% of the fleet. The degree of completion of the data and the quality of the information were very variable. For instance, only 77% of the questionnaires were answered in 1995 and 70% in 1996. The number of questionnaires filled in per port was also variable, ranging from 100% in Cala Rajada to 18% in Portocolom in 1996. The quality of the data was tested by the daily boat sales registers and personal interviews. The data considered as valid were used in the calculations.

Effort

For 1995 and 1996 two and three measures of effort were possible respectively. In Majorca each boat visits its FADs daily at sunrise, 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 there is no current, the haul is done around the FAD. If the catch is insufficient the fishermen search for floating debris to increase the catch. This is important in Port de Sóller where fewer FADs are moored.

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 that 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 the best chance of a catch. Thus, the number of

hauls is dependent on the biomass of dolphinfish present beneath the FADs. Hence the number of FADs and the number of effective fishing days can be used as a measure of effort. In 1996 the fishing time spent each day was also obtained.

Population dynamics

The population dynamics of dolphinfish was studied by means of VPA (Virtual Population Analysis). Since all the individuals caught in a season belong to the first year class, it is not possible to carry out a standard VPA with the year as the time unit (the unit defining both age and period of time in the catch-at-age data), so the time unit needed here must be smaller.

The reproductive and recruitment cycles of dolphinfish are annual in Mediterranean waters (Massutí and Morales-Nin, 1995). Although the life span of dolphinfish is several years, the fishery exploits only individuals in their first year, and during a maximum period of 5 months. Consequently, there is an unbalanced time scale between the life history and the fishery. A VPA carried out in such circumstances (small time unit and only on the first class individuals) should be interpreted in a different way to a standard VPA. Such a VPA analyses the recruitment trends over a period rather than the current population structure.

For 1995 a time unit of a week is possible, whereas for 1996 the time unit must be a fortnight, due to the low catches and irregular fishing trips caused by bad weather.

The data and parameters used to perform the VPAs were:

- Total weekly and fortnightly landings for 1995 and 1996.
- Catch-at-age tables, obtained from the length-frequency distributions, according to the sampling described above, and from age-length keys (age in days) obtained from otolith readings (Massutí *et al.,* 1999).
- Weight-at-age vector (Table 1), computed from the Von Bertalanffy growth parameters obtained by Massutí *et al.* (1999): L_∞= 102.5 cm, K= 1.834 yr^{-1}, t_0= -0.023 yr); and from the length-weight relationship obtained by the same authors: a = 0.011 $gr \cdot cm^{-3}$, b = 2.96.
- Lacking a better method for estimating the natural mortality (M) of the exploited first year class, M was computed according to Pauly's (1980) procedure using the above growth parameters, and from the mean surface water temperature during the year (17ºC). The value obtained was 1.74 yr^{-1} and was taken as constant for all ages.
- Morales-Nin (1996) obtained an F value of 0.154 $year^{-1}$. In the analyses this value was used as a reference for calculating terminal Fs. The terminal Fs, corresponding to ages of the catch-at-age tables, were set to this value according to the time unit: 0.003 $week^{-1}$ for 1995 and 0.006 $fortnight^{-1}$ for 1996. The terminal Fs corresponding to weeks (1995) or fortnights (1996) were tuned according to the effort in terms of days at sea. It was necessary to use an aggregate age class (24+ weeks) in the 1995 analysis.

TABLE 1. –Age, length and weight vector from Massutí *et al.* (1999).

Age (weeks)	FL (cm)	weight (g)
6	19.5	74.2
7	22.4	111.5
8	25.1	157.5
9	27.8	212.4
10	30.4	276.2
11	32.9	348.8
12	35.3	429.9
13	37.6	519.2
14	39.9	616.3
15	42.0	720.8
16	44.1	832.2
17	46.1	950.1
18	48.1	1073.8
19	50.0	1203.0
20	51.8	1337.2
21	53.5	1475.7
22	55.2	1618.2
23	56.9	1764.1
24	58.4	1913.0
25	60.0	2064.4
26	61.4	2217.9
27	62.8	2373.1
28	64.2	2529.6
29	65.5	2687.1

RESULTS

Historic landings data series

Only the annual landings can be presented for the 16-year series (Fig. 2), showing wide fluctuations from 2 metric tons to more than 120, with a mean of 63, a standard deviation of 35, and a slightly increasing trend (4 tons by year, with r^2= 0.3).

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 (Fig. 3). The effort data for this period showed that the fleet remained stable at around 50

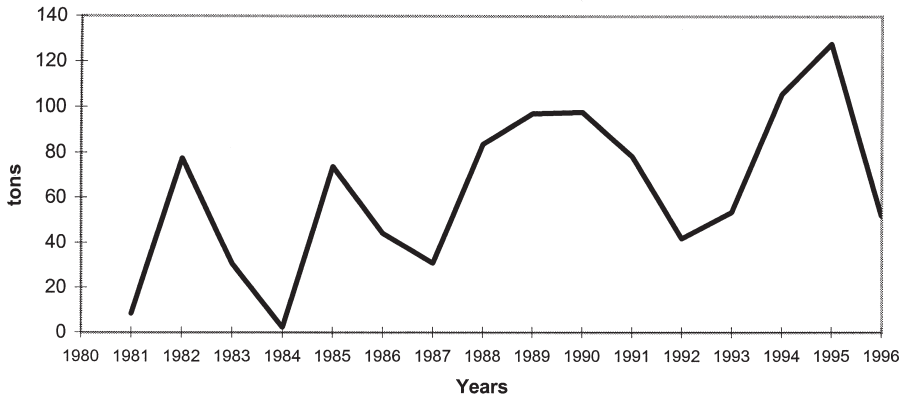

FIG. 2. – Historic data series of dolphinfish landings on Mallorca Island.

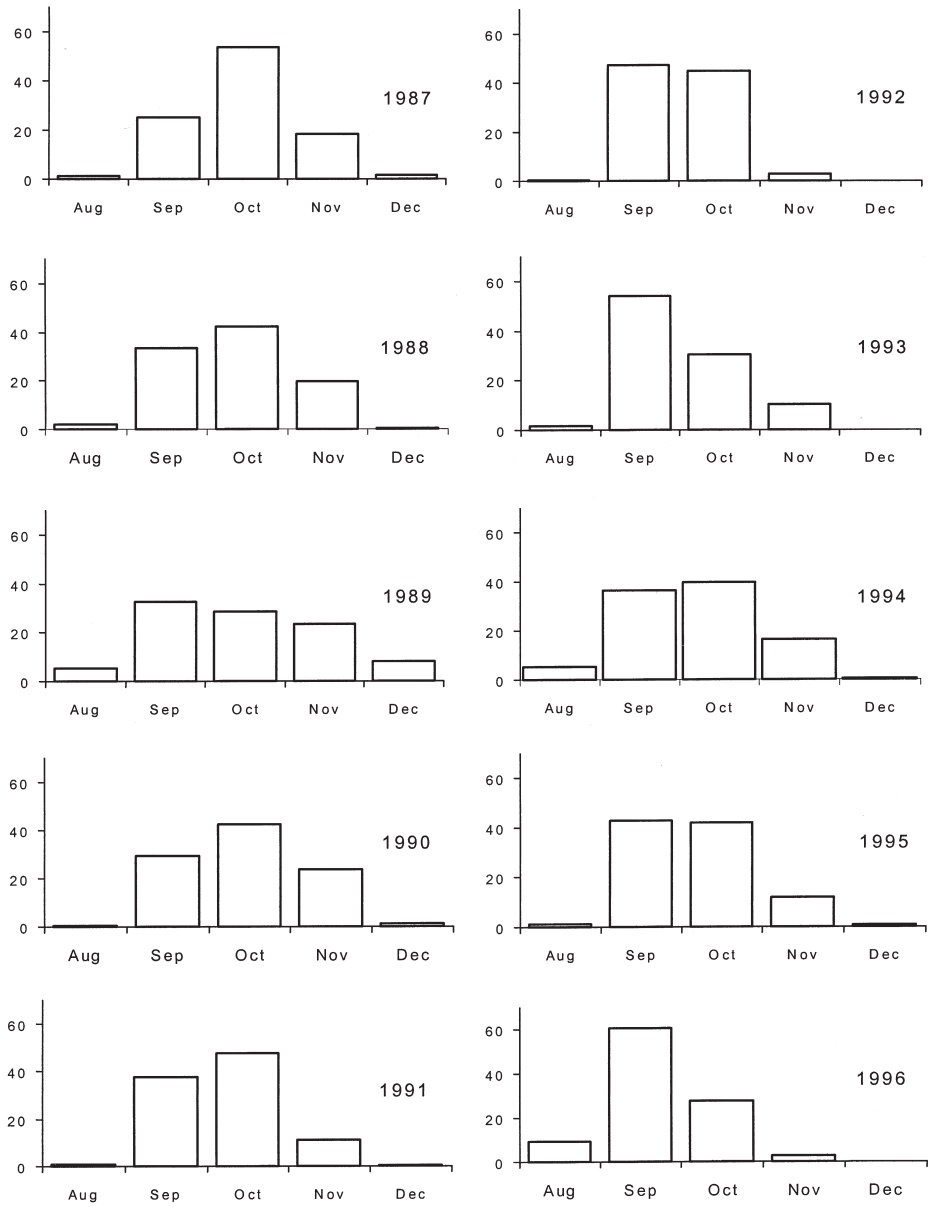

FIG. 3. – Annual dolphinfish landings by month on Mallorca Island.

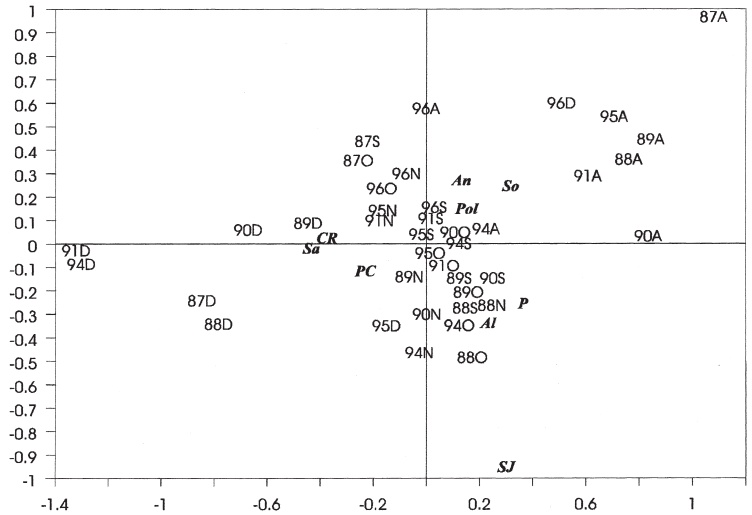

FIG. 4. – Correspondence analysis of the historic CPUE by port and month. Legends correspond to the year (two digits) and month of capture (A: August, S: September, O: October, N: November, D: December). Harbours indicated by: *SJ*: Sant Jordi, *Al:* Port d' Alcudia, *P*: Palma, *Pol*: Port de Pollença, *An*: Andratx, *So* : Port de Sòller, *Sa*: Cala Figuera, *CR*: Cala Rajada, *PC*: Portocolom.

boats. The number of boats per port ranged from 1 to 12, corresponding to Portocristo and to Port de Sóller respectively.

The correspondence analysis (Fig. 4) shows that the CPUEs are distributed along a temporal axis. The last fishing month (December) and the first fishing month (August) are at both sides, clearly differentiated. The distribution of the points did not follow a parabolic distribution, thus corresponding to a trend. When the harbours are considered, Colònia de Sant Jordi (SJ) was clearly differentiated. The rest were grouped in three associations: i) Port d' Andratx, Port de Pollença and Port de Sóller; ii) Cala Figuera, Cala Rajada and Portocolom; iii) Alcudia and Palma. The location of the harbour seems to determine these groupings, with the first one corresponding to the north coast, the second to the south east coast, and the third to harbours located in bays.

Fishing efforts and catches for 1995 and 1996

The number of FADs over time with seasons varied due to losses and renovations, which were not always reported. Thus, the data were corrected using the questionnaires and adjusted weekly. The number of boats fishing each week, the number of FADs per week, the number of fishing days and the weekly catch for each sampling port and fishing season were registered.

TABLE 2. – Effort per week measured as number of fishing days and number of FADs for the two fishing seasons sampled.

Week/year	Week	1995 E(days)95	1995 E(FADs)95	1996 E(days)96	1996 E(FADs)96
3August	1	18	832	27	733
4August	2	77	1188	58	1381
1September	3	138	1139	142	1389
2September	4	206	1130	102	1349
3September	5	153	1100	140	1308
4September	6	185	995	151	1273
1October	7	219	958	136	1181
2October	8	177	928	124	1035
3October	9	148	897	60	960
4October	10	178	868	91	864
1November	11	77	837	35	791
2November	12	85	759	24	781
3November	13	53	705	5	357
4November	14	73	723	7	188
1December	15	25	612	8	88
2December	16	7	280	0	72
3December	17	0	0	6	72

In both years there was a similar number of FADs and boats operating in the fishery and decreasing at the end. The number of fishing days followed an increasing trend in the 1995 fishing season, but in 1996 the number of fishing days decreased sharply at the end of October due to the bad weather. The low economic return of the fishery in 1996 determined the end of the fishing operations in early November.

The total annual catches were 128 metric tons and 52 metric tons in 1995 and 1996 respectively. The catches started in the second half of August and ended in November with some occasional catches in December in 1995, and the bulk of the catch in September and October. In general, the catches are greatest in the north at the beginning of the season, then greater in the south-east from October onwards. However, the weekly catch can fluctuate markedly, depending on fish availability and weather conditions.

Of the three effort measures for 1996, days and hours are very similar (r^2= 0.96), so hours have been eliminated from the analyses. FAD number and days are more different, with a correlation coefficient of 0.70 for 1995 and 0.85 for 1996. In general, it can be seen (Table 2) that as a measure of effort the number of days shows a greater variation than the FAD number.

ANOVA of the CPUEs from the 6 observed harbours (the observations being the fortnight

Table 3. Length composition of the dolphinfish landings on 1995 by forthnight.

	August		September		October		November		December		Total	Estimated
Forthnight	2º	1º	2º	1º	2º	1º	2º	1º	2º	number	Catch
Length (cm)											kg
21	1349	0	0	0	0	0	0	0	0	1349	124
22	2024	0	0	0	0	0	0	0	0	2024	213
23	3373	70	0	0	0	0	0	0	0	3443	414
24	2024	0	24	0	0	0	0	0	0	2048	279
25	4048	140	76	0	15	128	0	0	0	4407	678
26	2024	218	24	12	15	128	0	0	0	2421	418
27	675	1813	48	128	15	0	0	0	0	2678	518
28	675	2133	148	494	15	256	0	0	0	3720	801
29	6072	2849	216	430	85	0	0	0	0	9652	2304
30	0	2516	1113	1209	15	267	0	0	0	5120	1351
31	1349	4066	3026	762	85	0	0	0	0	9289	2702
32	0	4848	2165	1320	211	128	0	0	0	8672	2771
33	0	6083	1856	1878	226	48	5	0	0	10096	3533
34	0	5004	2786	2889	481	96	6	0	0	11262	4305
35	0	4826	2109	4633	530	48	5	0	0	12149	5061
36	0	5095	5145	4866	474	19	11	0	0	15611	7068
37	0	6399	5512	5781	874	307	14	0	0	18886	9273
38	0	2984	5995	8109	1387	471	36	0	0	18983	10086
39	0	3062	6094	7205	1603	892	209	3	0	19067	10941
40	0	1823	8959	4857	1883	543	488	3	0	18555	11476
41	0	1317	6216	5970	2927	1141	423	3	0	17997	11974
42	0	748	4497	7379	3224	1552	787	0	0	18187	12996
43	0	966	4332	4750	1968	1280	574	18	4	13892	10643
44	0	210	3138	3196	2552	1754	909	18	4	11780	9660
45	0	70	2409	2993	2519	1639	757	21	4	10412	9126
46	0	0	1813	3284	1802	979	699	45	12	8635	8077
47	0	0	1441	1868	1626	489	1010	8	0	6442	6422
48	0	0	646	1500	1063	1308	444	33	8	5003	5307
49	0	0	502	697	717	747	803	21	4	3491	3936
50	0	0	113	314	1091	443	405	35	8	2410	2885
51	0	0	89	209	460	330	595	84	25	1792	2274
52	0	0	120	314	528	573	373	50	12	1971	2650
53	0	0	976	93	228	237	557	21	4	2115	3008
54	0	0	0	129	359	97	190	48	12	835	1256
55	0	0	0	43	52	114	223	45	12	489	776
56	0	0	0	31	191	39	164	8	0	433	725
57	0	0	0	25	59	8	135	30	8	265	468
58	0	0	0	12	15	11	104	6	0	149	276
59	0	0	0	0	0	0	5	15	4	24	46
60	0	0	0	0	0	8	5	1	0	14	28
61	0	0	0	0	0	31	5	0	0	35	76
62	0	0	0	0	0	8	5	1	0	14	31
63	0	0	0	0	0	0	76	0	0	76	179
64	0	0	0	0	22	0	0	0	0	22	54
Total	23612	57240	71589	77380	29314	16120	10018	514	124	285912	167191

CPUEs) show no significant differences between port CPUE when effort is measured as the FAD number; furthermore, the variances between harbours are normal and not significantly different. On the other hand, when days are used as the effort measure, the variances of the CPUE by port are asymmetrical and means and variances differ significantly among harbours.

Length composition of the catches

The length composition of the catches was determined from 47 samples taken on board the fleet in 1995 and 17 in 1996 respectively. The fish length range was from 20 to 64 cm fork length in 1995 (Table 3) and from 23 to 64 cm in 1996 (Table 4). A total of 3,146 dolphinfish were measured in 1995 and 1,066 in 1996.

In both years the mean monthly length increased over the five month sampling period. The length composition showed 2-3 modes per month, including the mode of small fish at the end of October and November 1995.

In order to compare the length-frequency distributions between years, the correlation coefficients have been computed between both tables (fortnight and size class for 1995 and 1996), giving a correlation value of 0.556 with 414 degrees of freedom, and showing that both years were quite different from the point of view of size distribution sequence over the period.

Table 4. Length composition of the dolphinfish landings on 1996 by forthnight.

Forthnight	August	September		October		November		December	Total	Estimated
Length (cm)	2º	1º	2º	1º	2º	1º	2º	1º	number	Catch kg
21	0	21	0	0	0	0	0	0	21	2
22	0	123	42	0	0	0	0	0	165	23
23	0	394	0	0	0	0	0	0	394	61
24	0	275	0	0	0	0	0	0	275	48
25	0	292	0	0	0	0	0	0	292	56
26	0	501	0	0	0	0	0	0	501	108
27	0	678	0	0	0	0	0	0	678	162
28	0	669	293	1007	0	0	0	0	1970	520
29	317	567	539	0	0	0	0	0	1422	414
30	633	1158	664	23	0	0	0	0	2478	792
31	1267	2468	377	11	0	0	0	0	4122	1443
32	1900	3950	874	11	22	0	0	0	6757	2583
33	950	4821	790	0	0	0	0	0	6561	2733
34	633	5893	1988	46	304	0	0	0	8865	4014
35	633	5322	916	69	22	0	0	0	6962	3418
36	317	4789	2564	58	2261	0	0	0	9987	5307
37	0	3470	1575	24	281	0	0	0	5349	3069
38	0	1959	748	2037	138	0	0	0	4883	3020
39	0	1914	1617	104	493	0	0	0	4128	2747
40	0	1318	1700	58	299	0	0	0	3435	2454
41	0	452	670	162	2732	0	0	0	4074	3121
42	0	460	1784	2213	534	59	0	0	5166	4236
43	0	41	2569	4145	472	59	0	0	7286	6386
44	0	0	670	2166	490	176	0	0	3502	3276
45	0	0	628	141	312	59	0	0	1081	1078
46	0	0	1203	1089	237	176	0	0	2589	2746
47	0	0	335	1088	85	0	0	7	1574	1775
48	0	0	251	93	131	59	0	7	657	787
49	0	0	42	0	43	59	7	13	157	199
50	0	0	42	24	46	176	7	7	118	159
51	0	0	42	11	46	59	13	7	164	234
52	0	0	0	0	22	0	7	7	28	42
53	0	0	0	0	43	59	7	20	121	192
54	0	0	0	0	0	0	7	7	65	109
55	0	0	0	24	22	59	20	7	52	91
56	0	0	0	0	0	59	7	0	0	0
57	0	0	0	0	0	0	7	0	0	0
58	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	7	7	16
Total	6650	41534	22921	14605	9035	1053	78	85	95883	57418

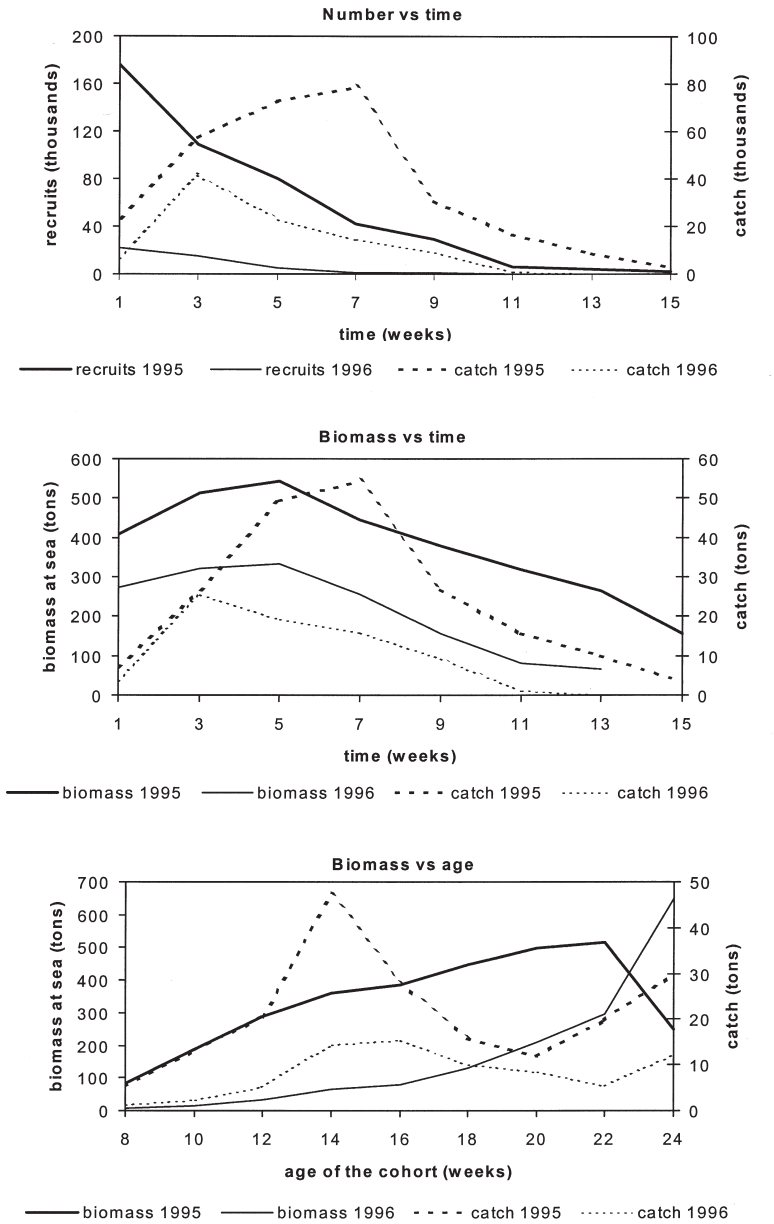

FIG. 5. – Trends in the catches, calculated recruitment and biomass of dolphinfish during the fishing season (vs. Time) and with age (vs. Age) for the two fishing seasons studied.

VPA

The results obtained from the VPA are presented in Figs. 5-7. Due to the lack of a means of converting catch to absolute abundance, the results (particularly trends) must be regarded in relative rather than absolute values. Moreover, our results might be somewhat biased because the VPA analysis is very sensitive to variations in M and we have assumed it to be constant although it is likely to be higher in the younger fish.

The comparison between 1995 and 1996 results shows that the population available was greater in 1995 than in 1996. The number of individuals for both years declined during the fishing season. On the other hand, the biomass increased during the 5 first weeks. The differences between 1995 and 1996 are apparent in the age composition of the number of individuals of the estimated population, those of 1996 being older than those of 1995.

The estimated total recruitment (individuals in the first unit of time) shows that in 1995 the figure was one order of magnitude greater than in 1996. Furthermore, although it declined in 1995, it did not do so as sharply as in 1996 (Fig. 6).

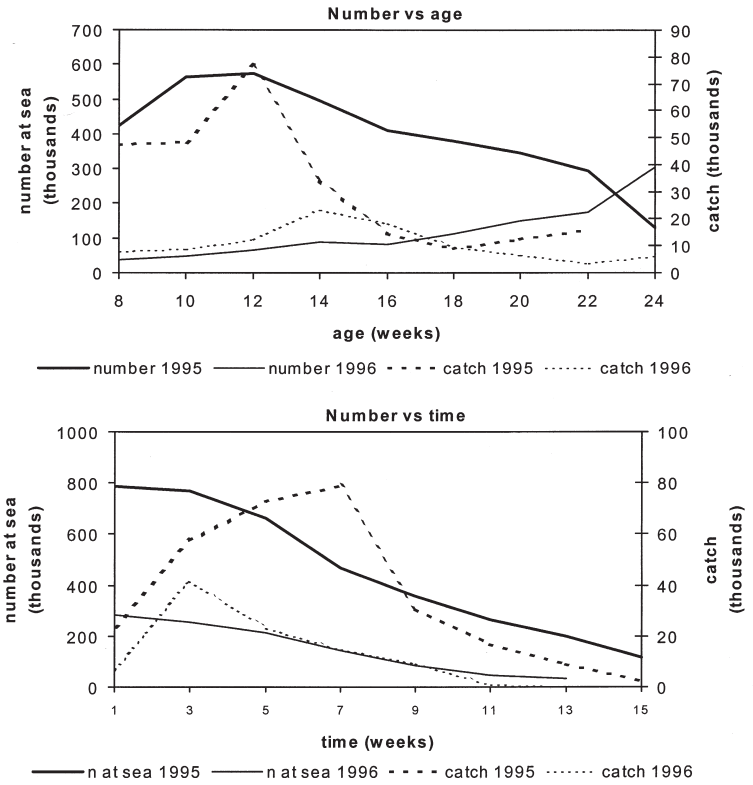

FIG. 6. – Age composition of the dolphinfish catch and calculated abundance with age (vs. Age) and during the fishing season (vs. Time) for the two fishing seasons studied.

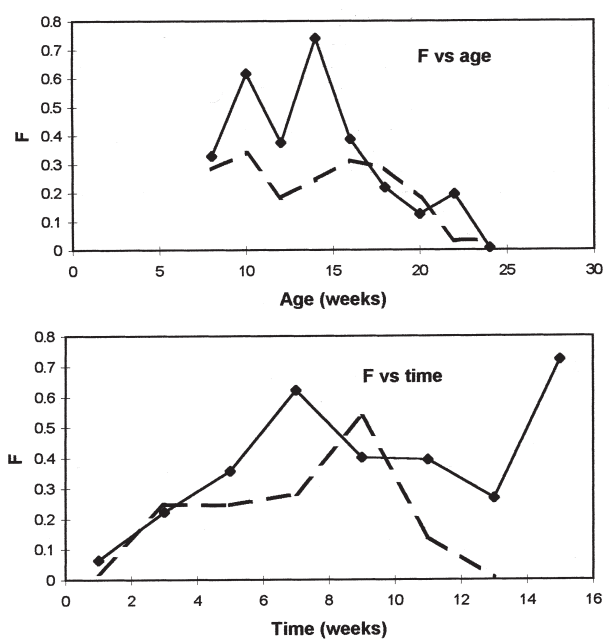

FIG. 7. – Dolphinfish fishing mortality at age (vs. Age) and during the fishing season (vs. Time) for the two fishing seasons studied.

The averages of Fs show slight differences between 1995 and 1996. Also, it seems that in 1995 mortality was greater in the younger fish than in 1996 (Fig. 7).

DISCUSSION

The time-series of landings and effort and the results of the two-year study showed marked fluctuations in catch and abundance. Since fishing exploits juvenile 0-age 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 in 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 of the recruitment of the species to the fishery. In the Mediterranean and other subtropical fish populations, in which the first year-classes are intensely exploited and annual catch fluctuations are observed, the ultimate explanation must be sought in the underlying environmental factors. They control the

"recruitment windows" and are more relevant than the existence of large or small spawning peaks (Pauly, 1987).

In order to to evaluate the impact of the fishery 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 the coast, all of which make the fishery very sensitive to bad weather. In 1996 the amount of fishing days decreased sharply due to very bad sea conditions in November-December.

The dolphinfish biology and distribution are also very relevant. For instance, the decrease in catches due to bad weather in 1996 should also depend upon the fish distribution in relation to land. During bad weather the fish probably remain further offshore.

Other important biological characteristics are: 1) the exploited fraction of the population is composed of 0-age class fish originating in the area with very fast growth rates; 2) dolphinfish is very mobile and can enter and leave the fishing area many times during the fishing season; 3) this is a migratory fish that will depart when the water temperature decreases and when it reaches a suitable size for migration. These characteristics have importance for the real value of M, but are difficult to quantify.

Recruitment failures in the population have a potentially enormous impact. These possible failures could explain the falls in the catches recorded in some years. These recruitment failures could be due, among other factors, to changes in environmental parameters and their effect on 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 is also changes in the environmental parameters. Therefore, this indicates the need to intensify research aimed at determining the environmental influences on the population dynamics.

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 (Samples and Sproul, 1985). Furthermore, in the management of the fishery the socio-economic aspects and the market have to be considered as management options.

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REFERENCES

Caddy, J.F. – 1990. Tendencias recientes en las pesquerías del Mediterráneo. *Análisis y estudios C.G.P.M.*, 63: 1-48.

Farrugio, H. and G. Le Corre. – 1993. A sampling strategy and methodology for assessment and monitoring of Mediterranean small-scale fisheries. *Sci. Mar.*, 57(2-3): 131-137.

Iglesias, M., E. Massutí, O. Reñones and B. Morales-Nin. – 1995. Three small-scale fisheries based on the island of Majorca (NW Mediterranean). *Boll. Soc. Hist. Nat. Balears*, 37: 35-58.

Massutí, E. and B. Morales-Nin. – 1991. La pesca de la llampuga (*Coryphaena hippurus*) en Mallorca. *Inf. Téc. Inst. Esp. Oceanogr.*, 96: 1-18.

Massutí, E. and B. Morales-Nin. – 1995. Reproduction and migration patterns of dolphin-fish (*Coryphaena hippurus*) in the Mediterranean Sea. *Sci. Mar.*, 59(2): 357-364.

Massutí, E. and B. Morales-Nin. – 1997. Reproductive biology of dolphin-fish (*Coryphaena hippurus* L.) off the island of Majorca (western Mediterranean). *Fish. Res.*, 30: 57-65.

Massutí, E., S. Deudero, P. Sánchez and B. Morales-Nin. – 1998. Diet and feeding of dolphin *(Coryphaena hippurus)* in western Mediterranean waters. *Bull. Mar. Sci.*, 63(2): 329-341.

Massutí, E., B. Morales-Nin and J. Moranta. – 1999. Otolith microstructure, age and growth patterns of dolphin (*Coryphaena hippurus*) (Pisces:Coryphaenidae) in the western Mediterranean. *Fish. Bull. U.S.*, 97(4): 891-899.

Massutí, E. , B. Morales-Nin and S. Deudero. – 1999. Fish fauna associated with floating objects sampled by experimental and commercial surrounding purse nets. *Sci. Mar.*, 63(3-4): 219-222.

Morales-Nin, B. (Coord.). – 1996. Biology and Fishery of Dolphinfish in the Western Mediterranean and Canary Island area. *UE DG XIV Project Nº94/031. Final Report,* Mimeo, 80 pp.

Samples, K.C. and J.T. Sproul. – 1985. Fish aggregating devices and open-access commercial fisheries: A theoretical inquiry. *Bull. Mar. Sci.*, 37(1): 305-317.

Scherrer, B. – 1983. Techniques de sondage en écologie. *In*: E.Masson (ed.), Stratégies d´échantillonnage en écologie, pp. 63-162. Paris.

Pauly, D. – 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. CIEM*, 39(2): 175-192.

Pauly, D. – 1987. Managing the Peruvian upwelling ecosystem: a synthesis. *In*: D. Pauly and L. Tsukayama (eds.), *The Peruvian anchoveta and its upwelling ecosystem: three decades of change. ICLARM Studies and Reviews*, 15: 325-342.