

NOTE

Sexual development, maturity and reproduction of dolphinfish (*Coryphaena hippurus*) in the western and central Mediterranean*

A. POTOSCHI¹, O. REÑONES² and L. CANNIZZARO³

¹Dipartimento di Biologia Animale ed Ecologia Marina, Università di Messina, Salita Sperone, 31, 98166 S. Agata, Messina, Italy. E-mail: antopoto@isengard.unime.it

²IEO - Centre Oceanogràfic de les Balears, P.O. Box 291, 07080 Palma de Mallorca, Spain.

³Istituto di Ricerche sulle Risorse Marine e L'Ambiente, via Luigi Vaccara, 61 - 91026 Mazara del Vallo, Sicily, Italy.

SUMMARY: Studies have been conducted on the sexual development, maturity and reproduction of the dolphinfish (*Coryphaena hippurus* L., 1758) in the Mediterranean area, with special reference to the Balearic islands and Sicily. Professional fishing, carried out from August to December 1996, uses FADs (Fish Attracting Devices) and surrounding nets. 2087 juvenile specimens of dolphinfish from the Ionian and southern Tyrrhenian seas, the Strait of Sicily and the Balearic islands were sampled. A small number of adult fish (39), which are not usually caught in surrounding nets, was sampled in the swordfish long-line by-catch. The gonads of the young fish were analysed monthly to establish the stage of development of the ovaries or testes, during the first few months of life. The gonads of the adult fish, sampled in the months of June-September only, were all mature. The specimens caught between October and December presented maturity stage V in the case of the females and I in the case of the males, indicating the end of the reproductive period. The gonado-somatic index (GSI) and condition factor (CF) were calculated for both genders. The trend of the GSI confirms the presence of immature specimens as regards the juvenile fish; the low value of GSI was obtained for the adults, probably associated with the post-reproduction conditions found in the October-December period. Most of the gonads sampled during the months between August and December belonged to young specimens born in early summer. This is confirmed by the juvenile stages (FL 2.5 to 4.3 cm) caught with plankton nets in the Strait of Messina area in July.

Key-words: sexual development, maturity, reproduction, dolphinfish, *Coryphaena hippurus*, Mediterranean.

INTRODUCTION

Dolphinfish, *Coryphaena hippurus* L., 1758, appear in commercial catches from August 1996 to January 1997 off eastern and western Sicily (Potoschi and Sturiale, 1996; Bono *et al.*, 1997), off the Balearic island (Cabo, 1961; Iglesias *et al.*, 1994; Massuti and Morales-Nin, 1991) and off Malta

(Galea, 1961). Although many authors have conducted studies and research into the reproductive biology of this species in other seas of the world (Williams and Newell, 1957; Beardsley, 1967; Soichi, 1978; Goldberg and Tresierra, 1985; Schuck, 1951; Shcherbachev, 1973; Chatterji and Ansari, 1982; Ditty *et al.*, 1994), little is known about the Mediterranean population (Bannister, 1976). Recently Massuti and Morales-Nin (1995, 1997) have considered sexual dimorphism, sex ratio, sizes

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of early sexual maturity and fertility in specimens captured in the western Mediterranean.

Specific projects funded by the Ministry of Agriculture, Food and Forest Resources for Italian seas (Potoschi, 1995) and by the European Commission, (contract n° 94/031 and 95/073) have considered aspects of fishing and of the biology of the species in the central Mediterranean. The aim of this work is to value the reproductive characteristics of samples captured in the western and central Mediterranean.

MATERIALS AND METHODS

During the 1996 fishing season, 2087 juvenile specimens of dolphinfish, with FL of between 20 and 60 cm, from the Ionian sea, southern Tyrrhenian sea, the Strait of Sicily and the Balearic islands were sampled. In these areas the catches are in fact made in the period, known as the period of recruitment, in which the size (cm) of the samples is part of the commercial catch using surrounding-nets and FADs positioned prior to the fishing season.

Only 39 adult specimens (over 60 cm FL) were sampled during the year as a by-catch of the commercial long-line, drifting-net and harpoon for swordfish (*Xiphias gladius* L. 1758).

All individuals were measured for fork length (FL) and total length (TL) to the nearest cm, total weight (TW) and gutted weight (GTW) to the nearest 0.1 g, and weight of the gonads (GW) to the nearest 0.01 g. The sex was determined by a macroscopic examination of the gonads, and stages of maturity were determined using Beardsley's macroscopic scale (1967) (5 stages for females and two for males). Sex has also by presence of a prominent bony crest which is a characteristic of male individuals and is absent in females (Beardsley, 1964). This sexual dimorphism was observed in 1014 specimens with FL longer than 45 cm.

An examination of the gonads of 195 specimens was performed by means of histological preparations. The gonad samples analysed histologically were divided by sampling month to check for any changes in the organization of both testes and ovaries during the first months of life. Histochemical stains such as periodic Schiff acid and Alcian blue were only used on some specimens of adult individuals, more particularly on the ovary sections at an advanced stage of development obtained in the June-July samplings, to highlight neutral and acid mucopolysaccharides respectively, and Coomassie blue to colour the protein mate-

TABLE 1 - Sex ratio (M: males; F: females) for juvenile and adult dolphinfish caught by surrounding net and long line respectively (N: number of specimens), in the central and western Mediterranean.

Area	N	M%	F%
	Juveniles		
Balearic islands	227	32.6	67.4
Southern Tyrrhenian	658	30.5	69.5
Ionian Sea	432	31.9	68.1
Strait of Sicily	770	31.2	68.8
Adults			
Balearic islands	30	56.6	43.4
Ionian Sea	5	40	60
Strait of Sicily	4	0	100

rial in oocytes at various stages of development. The gonosomatic index (GSI) was calculated by the following formula: $GSI = \text{gonad weight (g)} \times 100 / \text{gutted body weight (g)}$, and the condition factor by the formula: $CF = \text{weight (g)} \times 10^5 / \text{fork length (cm)} \times 10^3$.

RESULTS

Sex ratio

Table 1 shows the analysis of sex ratio for the juvenile specimens (20-60 cm FL) and adults (over 60 cm FL) sampled. The ratio between the sexes is 2:1 (females : males) for the juvenile samples, while the sex ratio for the adults is different in the various areas considered. The distribution of the sexes of juvenile samples by month and length (FL in cm) is represented in Figures 1 and 2 respectively.

The results of sex ratio confirm the information given by Bannister (1976) for the Maltese islands, and by Cabo (1961) and Massutí and Morales-Nin (1991, 1997) for the Balearics. For eastern Africa this ratio reaches the value of 4:1 (Williams and Newell, 1957); (Rose and Hassler, 1968, 1974). For the waters of North Carolina, workers separated their samples by age groups, confirming a sex ratio of 2:1 for those belonging to 0 age group, while for higher ages the sex ratio was 1:1. In our data the few adults sampled, whose sex ratio is given in Table 2, confirm that the ratio between the sexes appears to be conditioned by the size of the specimens.

Sexual maturity

The GSIs calculated for the juvenile fish are shown in Table 2. From these it can be seen that the

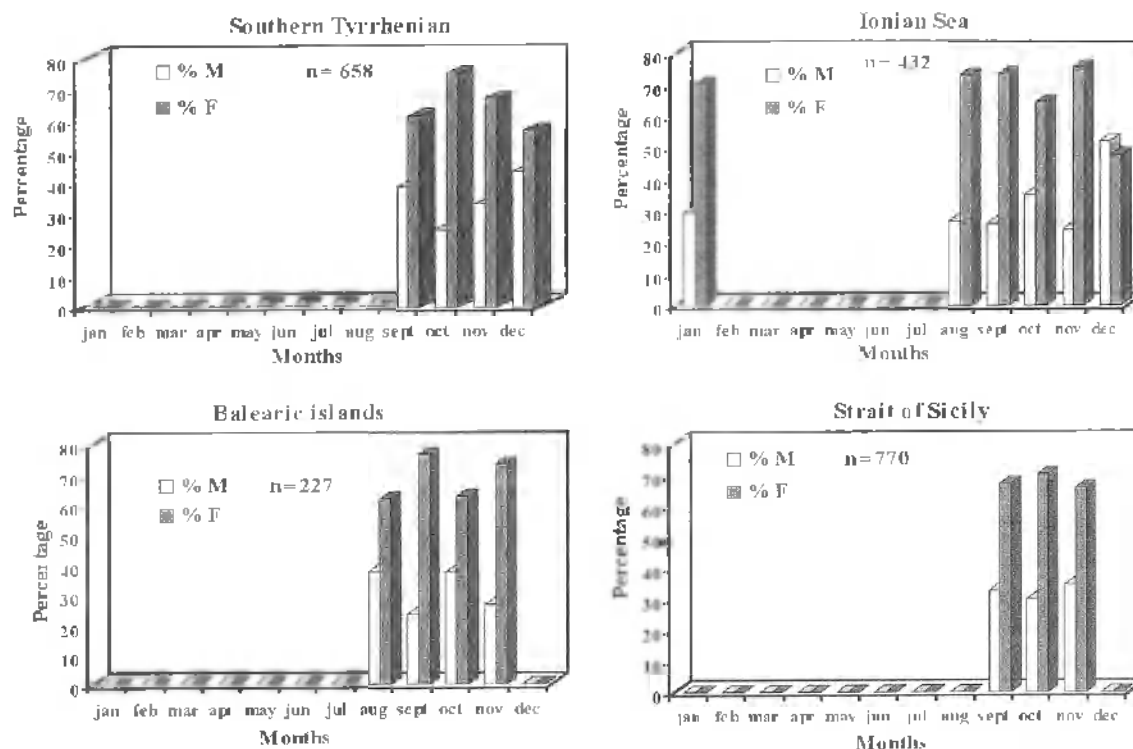


FIG. 1. – Monthly sex ratio (M: males; F: females) for juvenile dolphinfish caught in the Central and Western Mediterranean (n: number of specimens).

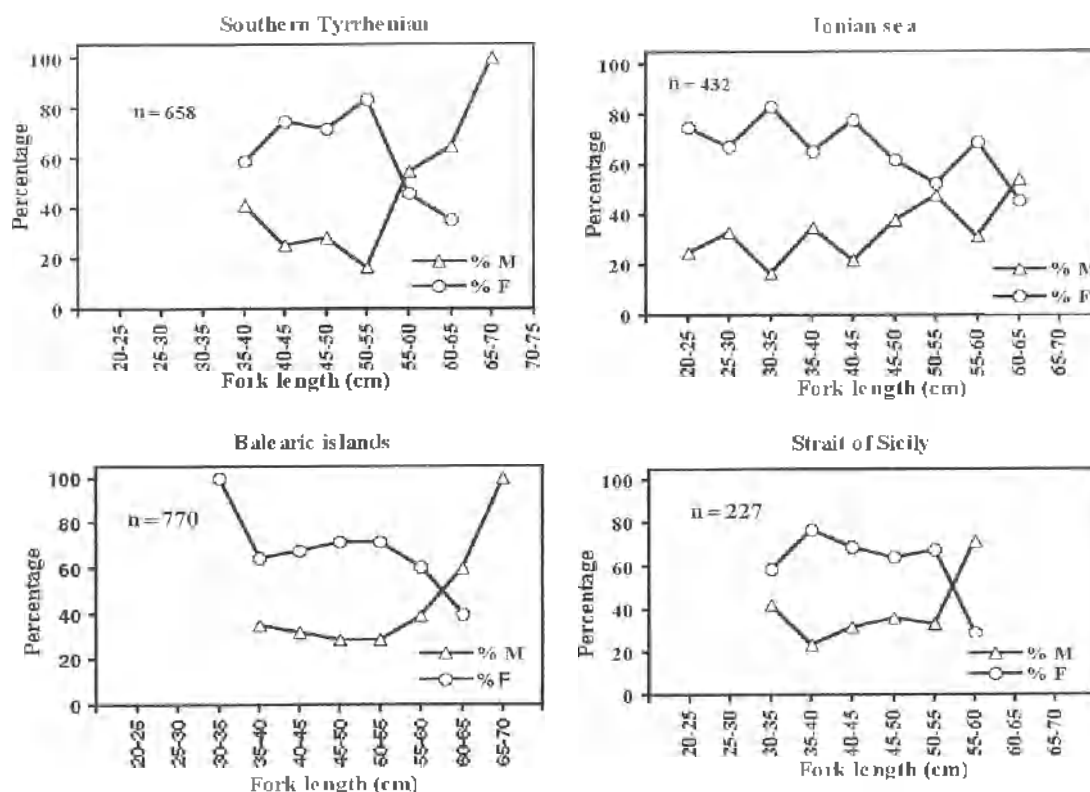


FIG. 2. – Sex ratio (M: males; F: females) for juvenile dolphinfish caught by surrounding net (n: number of specimens) in the central and western Mediterranean, shown separately for each size class.

TABLE 2. - Values of GSI (SD: standard deviation) for juvenile dolphinfish caught in the central and western Mediterranean, by month, separately for males (M) and females (F).

Months	Southern Tyrrhenian				Strait of Sicily				Balearic islands				Ionian Sea			
	M	SD	F	SD	M	SD	F	SD	M	SD	F	SD	M	SD	F	SD
Aug '96									0.322	0.026	0.433	0.093	0.803	0.702	0.795	0.685
Sept '96	0.106	0.232	0.539	0.180	0.114	0.224	0.563	0.221	0.155	0.223	0.492	0.151	0.112	0.225	0.366	0.167
Oct '96	0.414	0.137	0.619	0.220	0.106	0.220	0.599	0.209	0.120	0.337	0.754	0.308	0.182	0.226	0.548	0.154
Nov '96	0.129	0.309	0.736	0.306	0.111	0.304	0.679	0.216	0.111	0.405	0.720	0.223	0.181	0.273	0.865	0.504
Dec '96	0.164	0.352	0.859	0.365									0.071	0.373	0.822	0.258
Jan '97													0.133	0.387	0.875	0.323

TABLE 3. - Values of GSI (SD: standard deviation) for adult dolphinfish caught in the central and western Mediterranean, by month, separately for males (M) and females (F).

Months	Strait of Sicily		M	SD	Ionian Sea		M	SD	Balearic islands		SD
	F	SD			F	SD			F	SD	
May '96			0.292	0.295							
Jun '96					6.513	3.79					
Jul '96	1.984	0.851	1.382	0.365	10.454	6.844	1.034	0.198	4.82	4.159	
Aug '96					3.093	1.497	1.385	0.471			
Sept '96							0.752	0.258	3.38	4.7	
Oct '96	1.399	0.455									
Nov '96											
Dec '96	0.727	0.227									

sampled individuals, coming from commercial fishing, have a size of 20 to 60 cm FL, so the very low GSI values are a further demonstration that these are immature individuals belonging to the 0 age group (Table 2).

This was also confirmed by the analysis of the stages of maturity of the gonads of the adult specimens, whose graphic representation of the monthly distribution (Table 3) shows how the period of spawning in the areas considered, for both sexes, is from June to September, with the maximum value in July, though in October mature males were found as a proof that germinating activity of the male gonad extends a few months longer than that of the females.

The condition factor (CF), differentiated by fishing equipment and hence by size, confirms the presence of only immature specimens in catches with surrounding-nets. The individuals caught by long-lines show lower values in September and October, probably linked to a post-spawning condition (Table 4).

Histological analysis

The few samples obtained between June and July are the only ones in which it was possible to study some aspects of the maturation of the gonads in adult individuals. The females sampled during this period showed maturing ovaries. It was only possi-

ble to describe some stages of the development of the oocytes because mature ovaries with hydrated oocytes and spawning ovaries, characterised by the presence of post-ovulatory follicles, were not sampled. The cytological features of all the stages of development of the cells of the male germinative line were observed. These observations showed that the reproductive period of adult males ends in October. The histological examination of the gonads showed that:

- the gonads are fully differentiated even in juvenile specimens (0 age group);
- the juvenile females have ovaries which can macroscopically be defined as stage I or II;
- histologically these gonads can be defined as stage I or immature;
- the change in some macroscopic characteristics (colour, shape etc.) does not correspond to important histological changes;
- the young males have early development of the gonad and parts of the germinative line.

DISCUSSION

From the biological aspects taken into consideration in the individuals coming from the central Mediterranean it is clear that there are no significant differences in the habits shown by the species.

TABLE 4. — Condition factor (SD: standard deviation; n: number of specimens analysed) for dolphinfish caught in the Central and Western Mediterranean, shown separately by area and method of capture for males and females.

Females			May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan
Ionian sea	Surrounding net	mean SD n				0.502 0.395 74	0.919 0.083 54	0.091 0.094 46	0.838 0.120 51	0.848 0.074 33	0.849 0.070 36
Southern Tyrrhenian	Surrounding net	mean SD n					0.787 0.088 57	0.859 0.096 270	0.867 0.090 91	0.817 0.84 39	
	Long-line	mean n		0.690 1	0.795 1	0.885 1					
Strait of Sicily	Surrounding net	mean SD n					0.824 0.064 215	0.837 0.067 292	0.857 0.048 23		
	Surrounding net	mean SD n				0.909 0.668 13	0.987 0.703 42	0.893 0.089 75	0.916 0.057 22		
Balearic Islands	Long-line	SD n		0.791		0.909					
					0.136 14		0.088 3				
Males											
Ionian sea	Surrounding net	mean SD n				0.463 0.116 27	0.903 0.079 19	0.886 0.086 25	0.863 0.063 16	0.891 0.085 36	
Southern Tyrrhenian	Surrounding net	mean SD n					0.841 0.078 36	0.858 0.098 90	0.939 0.115 40	0.880 0.067 30	
	Long-line	mean n	1.020 1		1.004 1						
Strait of Sicily	Surrounding net	mean SD n					0.867 0.064 105	0.866 0.059 123	0.997 0.249 12		
	Long-line	mean n			0.956 1			0.993 2		1.196 1	
Balearic Islands	Surrounding net	mean SD n				0.939 0.064 8	1.079 0.067 13	0.951 0.079 45	0.998 0.045 8		
	Long-line	mean SD n			1.021 0.414 8	1.235 0.032 3	1.124 0.005 2				

Indeed, the results obtained confirm that the sex ratio remains in favour of the females for sizes of between 20 and 50 cm FL, while it is equal in individuals larger than 50 cm. Recently Massutí and Morales-Nin (1997), for the western Mediterranean, also report the ratio of 1:1 linked to the size (63-117 cm FL) of the samples. The morphological difference between males and females in samples with an FL greater than 45 cm, given from presence of a prominent bony crest in males, represents a valid method for identifying the sex as indicated by Beardsley (1967) and by Massutí and Morales-Nin (1997).

From the analysis of the values obtained by calculating the GSI and CF and from the monthly distribution of the stages of maturity of the gonads, it can be claimed that the Mediterranean definitely represents a spawning area where the specimens of the period of recruitment find favourable environ-

mental conditions which cause a temporary aggregation under the FADs, and good availability of food which allows the species to grow rapidly. The change in the environmental conditions, due to the arrival of winter, results in departure of the species from the areas studied to warmer waters (Gibbs and Collette, 1959; Massutí and Morales-Nin, 1995). In the winter even accidental catches of dolphinfish are not recorded in the areas investigated. The absence of dolphin fish did not enable samples to be taken over the whole year, particularly between March and June. Nevertheless, it can also be stated that the reproduction period of the species lasts at least four months (June-September); in fact, in the area of the Strait of Messina, 4 specimens with FL of 25 to 43 mm were caught in July and one specimen with 48 mm FL in October, definitely representing two birth times of the extended spawning period.

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