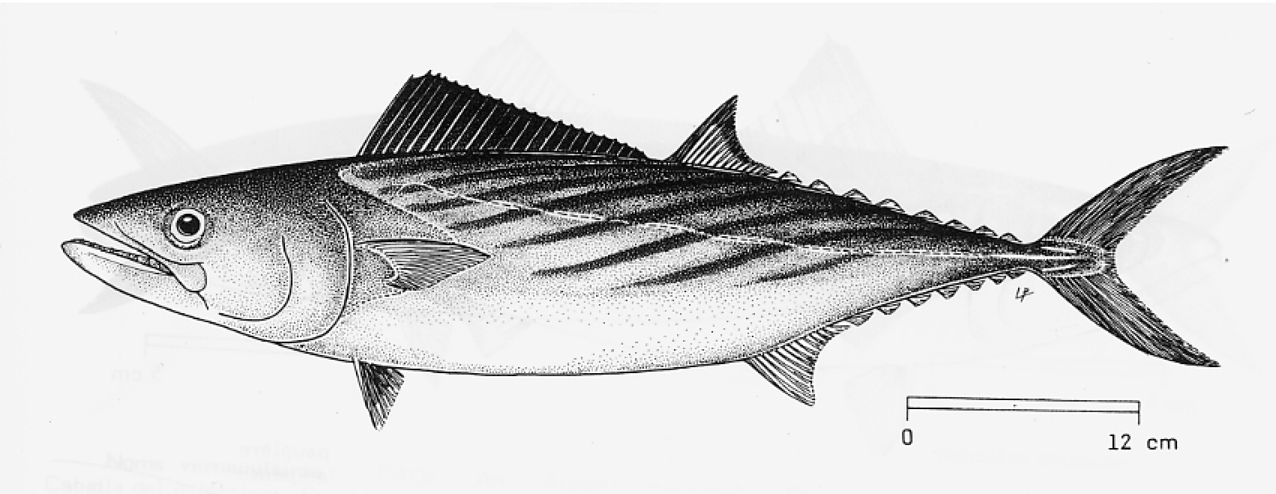
2. BIOLOGY AND ECOLOGY OF SMALL TUNAS IN THE MEDITERRANEAN AND THE BLACK SEAS

This section of the report includes the available information on the life history of the main species of small tunas present in the Mediterranean Sea and in the Black Sea, according to various scientific sources, with particular attention to the biological parameters useful for stock assessment.

As far as the biology is concerned, it was decided only to take into account the specific features reported for the study area, substituting them with worldwide references if the local information was not available. Length frequencies have been collected by several fisheries and they have been summarized herein by species.

2.1 *Sarda sarda* (Block, 1793)



The Atlantic bonito, *Sarda sarda* (Block, 1793) (ICCAT code BON) is an epi-pelagic neritic schooling species which lives in a large range of water temperatures (12–27°) and salinities (14–39‰), sometimes reported entering estuaries (Collette and Nauen, 1983).

Its **distribution** is in tropical and temperate waters of the Atlantic and Mediterranean, including the Black Sea. On the East side of Atlantic the distribution appears uninterrupted from Scandinavia to South Africa; on the West side, it presents interruptions in the Caribbean Sea and South of the Amazon River to Northern Argentina.

The **maximum size** in the Atlantic is 91.4 cm (Collette and Nauen, 1983), in the Mediterranean it is 96 cm (Ionian Sea, De Metrio *et al*., 1998) and in the Black Sea it is 90 cm (Kara, 1979).

The **diagnostic features** are well known (Collette and Nauen, 1983): upper jaw teeth 16 to 26; lower jaw teeth 12 to 24; gillrakers 16 to 23 on first arch. Dorsal fin 20–23 spines; dorsal finlets usually 8; anal fin 14–17 rays; anal finlets usually 7; pectoral fin 23–26 rays. Vertebrae: 26–28 precaudal plus 23–27 caudal.

The meristics of dorsal fin and vertebrae are higher than the other three species of Sarda [*S. australis* (Macleay, 1880), *S. chiliensis* (Cuvier, 1831), *S. orientalis* (Temminck and Schlegel, 1844).

More detailed information about biometric and meristic characteristics can be found in Demir (1964) and Franicevic *et al.* (2005).

2.1.1 Migrations

In the Western and Central Mediterranean Atlantic bonitos are mainly fished in coastal waters, but large specimens (60–85 cm FL) are also present offshore; observations made while studying the swordfish fishery in the Italian waters ascertained a distance from the coast of about 15 nm, at a depth of more than 2 000 m in the Ligurian Sea and a large distribution offshore, even over very deep bottoms in the Central and Southern Tyrrhenian Sea.

In the Eastern Mediterranean migrations from the Black Sea to the Aegean Sea and viceversa have been studied since the fifties by tagging techniques (Demir, 1957). The water temperatures possibly influencing fish movements were also recorded (Acara, 1957). There are large spawning grounds in the Black Sea, which give huge quantities of young fish not only moving along the Southern coast of the same sea, but also migrating in autumn to the Marmara Sea and in part to the North Aegean. Where the Black Sea is concerned Atlantic bonito moves to the southern Black Sea coast in May–July, forming shoals and staying in the same area from the autumn/winter period until the beginning of March. Individuals of age 1 probably migrate to the same region for feeding. All these locations represent fishery areas of the Turkish fleet (Oray, Karakulak and Zengin, 1997).

During the spring, with a reverse migration, adult fish reach the spawning areas of the Black Sea; restrictions have been enforced on fishery from April to September to protect the spawning season. Each year class strongly influences the production and can trigger oscillations within a period of several years. In the seventies severe environmental decay occurred in the Black Sea and since then large migratory species such as bluefin, swordfish, little tunny and bluefish have disappeared. The Atlantic bonito is no longer available throughout the area, but is apparently limited mainly to the southern part of this sea.

Atlantic bonitos tagged on the Spanish Mediterranean coast (Rey, Alot and Ramos, 1984) have shown that: 1) the fish can move along the coast in both South and North directions; 2) a specimen covered about 370 nm in less than 4 months, travelling towards Gibraltar from Castellon to Estepona (Rey and Cort, 1978).

A consistent fraction of fish tagged at the tuna trap of Ceuta was recovered in the Atlantic, both South and North of the Straits, from Morocco to Portugal (Rey and Cort, 1981). According to these scientific data, the distribution of the local population of *S. sarda* would not seem to be strictly confined to the Mediterranean Sea, but it is so far not known if Atlantic specimens (which have their spawning grounds along the Atlantic coast of Morocco (Dardignac, 1962) also move across the Strait toward the Mediterranean.

It is likely that, from a management point of view, the Mediterranean and Black Sea stock can be considered as separate management units from the Atlantic stock, even if the exchange rate between the Atlantic Ocean and the Mediterranean and between the Mediterranean and the Black Sea are not known. The boundaries of this stock along the eastern Atlantic coast outside Gibraltar are yet to be defined. According to the data presented in this report, sub-stocks might be distinguished in the Western-Central and Eastern side of the Mediterranean Sea including the Black Sea.

2.1.2 Biological characteristics

Many studies on the fishery biology of *Sarda sarda* have been carried out in the Eastern area (Zusser, 1954; Nümann, 1955; Slastenenko, 1956; Demir, 1957, 1963, 1964; Krotov, 1957; Mayorova and Tkacheva, 1959; Porumb and Porumb, 1959; Nikolov, 1960; Demir and Demir, 1961; Kutaygil, 1965).

Recent data on the biological characteristics of this species, with implications for its management, have been studied both in the Eastern and Western Mediterranean and allow for the comparison of potentially different population units. According to a recent summary of information about Atlantic bonito of the Western and Central Mediterranean, a possible stock unit on the basis of genetic difference (Viñas, Alvarado Bremer and Pla, 2004) might be present in these areas (Orsi Relini *et al.*, 2005).

The **length/weight** relationships were studied by several scientists and the published findings are shown in Table 2 and in Figure 1. It is known that more recent data have been collected by some EC countries thanks to the EC-DCR national programmes, but these results have not been published yet.

Table 2 – Length/weight relationships in *Sarda sarda* in the Mediterranean and Black Seas

Function	N	Range FL (cm)	Range W (g)	Author	Area	Notes
$W=0.01486LF^{2.9719}$	165	40–55.5		Rodriguez-Roda, 1966	Gibraltar	–
$W=0.02361LF^{2.8703}$	1608	14–90	80–7500	Kara, 1979	Aegean, Marmara, Black Sea	
$W=0.00724LF^{3.1644}$	878	19–72	200–5500	Rey, A lot and Ramos, 1984	Gibraltar (Med-Atl)	M+F+Indet.
$W=0.00653LF^{3.1865}$	242	33–65.2	436–4040	Rey, A lot and Ramos, 1984	Mediterranean Atlantic	M
$W=0.00844LF^{3.1218}$	229	33–70.5	460–4866	Rey, A lot and Ramos, 1984	Mediterranean Atlantic	F
$W=0.0252LF^{2.83}$	845	–	–	Giacchetta *et al*., 1995	Gulf of Taranto	M+F
$W=0.0039LF^{3.3263}$	–	21.8–70.5	110–5000	Oray, Karakulak and Zengin, 2004	Turkey	–
$W=0.0038LF^{3.3414}$	285	35–67	–	Franicevic *et al*., 2005	Adriatic Sea	M
$W=0.0056LF^{3.2364}$	353	33–64.5	–	Franicevic *et al*., 2005	Adriatic Sea	F
$W=0.0085LF^{3.1230}$	665	33–67	–	Franicevic *et al*., 2005	Adriatic Sea	M+F
$W=0.03LF^{2.8323}$	240	35–82	700–7050	Di Natale *et al*., 2006	Tyrrhenian Sea	–
$W=0.4LF^{2.1813}$	109	35–67	800–4000	Di Natale *et al*., 2006	Strait of Sicily	–
$W=0.0094632LF^{3.1011}$	–	–	–	Macias *et al*., 2006	Spanish Mediterranean Traps	–

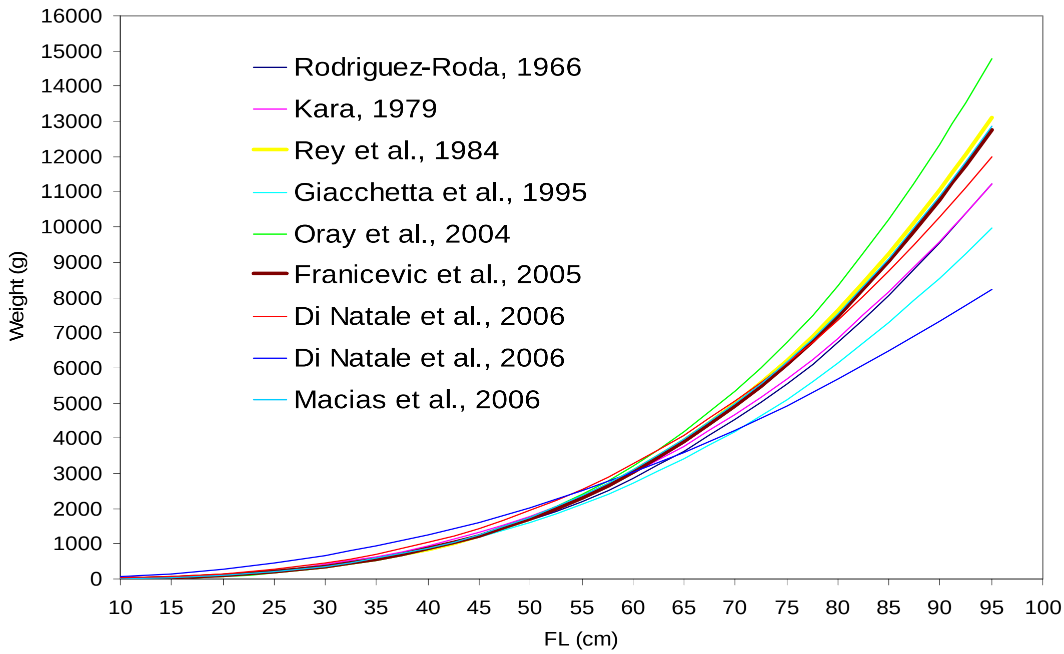


Figure 1 – Length/weight relationships of *Sarda sarda* in the Mediterranean Sea

The **reproductive season** shows a remarkable variability, according to several authors. It is likely that it occurs largely from May to July in most of the Mediterranean Sea, with some yearly variation in March or April according to the areas, concentration or oceanographic features. It the Black Sea reproduction takes place in the second part of the spring, sometimes extending up to July. The optimal water temperature for spawning in the Black Sea is 18 °C (Majorova and Tkecheva, 1960).

Table 3 – Spawning periods and grounds of *Sarda sarda* in the Mediterranean and Black Sea

AREA	**PERIOD**	**AUTHOR**
Sicily	May 20 – June 30	Sanzo, 1932
Algerian coasts	March – May	Dieuzeide, 1955
Gibraltar	May – July	Rodriguez-Roda, 1966
Black Sea	May to mid June	Demir, 1957
Black Sea	June to mid July	Mayorova and Tchaceva, 1959
Mediterranean and Atlantic Morocco	June – July	Rey *et al.*, 1984
Catalan coast	May to July	Sabates and Recasens, 2001
Southern Tyrrhenian Sea	May to July	Di Natale (pers.com.)
Straits of Sicily	April to June	Di Natale (pers.com.)
Ligurian Sea	May to July	Orsi Relini (pers.com.)

When describing basic characteristics of *S. sarda*, the most difficult subject is **growth**. Reading of **age** on skeletal pieces is difficult and seems to produce different results compared to the study of length/frequency distributions (cfr. Table 4). The latter are very important in this species because the reproductive season is short (Table 3) and therefore, in length/frequency distributions, the cohorts are clearly identified.

Samples obtained by longlines and drifnets in offshore waters generally have a limited component of young fish. Coastal traps for tuna, such as those of Spain and Italy, represent important opportunities for the study of the young classes. Turkey's unique geographical position provided by the Straits of Bosphorus offers a privileged observation area for young bonitos.

Table 4 – Length at age, in centimetres, of *Sarda sarda*

	Age group						
Author	**0**	**1**	**2**	**3**	**4**	**Method**	**Area**
Nümann (1955)	–	38–41	53–57	60–64	–	l/f distributions	Turkish waters
Kutaygil (1965)	–	–	58	64.8	68	otoliths	Turkish waters
Rodriguez-Roda (1966)	–	43.48	51.46	62	–	l/f distributions	Gibraltar
Rodriguez-Roda (1981)	42.59	50.51	60.50	64.00	–	vertebrae	Gibraltar
Rey *et al*. (1984)	46.0	51.71	57.04	63.15	–	–	Gibraltar
Rey *et al*. (1986)	37.03	51.71	57.04	63.15	71.00	otoliths, vertebrae, fin rays	Gibraltar
Santamaria *et al*., (1998)	34.8	50.9	57.5	64.8	70.4	Fin rays, vertebrae	Ionian Sea
Oray *et al*. (2004) quoting Nümann	–	41	52–57	61–64	–	–	Turkish waters
Di Natale and Mangano (in press)	38.63	54.40	56.50	64		Fin rays	Tyrrhenian Sea 2002
idem	40.80	50.92	61.40	71		Fin rays	Tyrrhenian Sea 2003
idem	38.83	45.69	57.80			Fin rays	Tyrrhenian Sea 2005
idem	39.50	50.25	59	66		Fin rays	Tyrrhenian Sea 2006
idem	40.50	49.65	59.43			Fin rays	Straits of Sicily 2006
Santamaria *et al*., (2005)	Juvenile growth 10.5–39.8 FL in 18–110 days					otoliths	Southern Italian seas

The Von Bertalanffy growth functions reported so far for the Mediterranean Sea are the following:

Rey *et al*., 1986	L inf = 80.87; K = 0.35; t0 = -1.70
Santamaria *et al*., l998	L inf = 80.60; K = 0.36; t0 = -1.37

Many studies were available for *Sarda sarda* from the Black Sea, including contrasting “slow” growth series of length at age with a longevity of 9 years (74–85 cm at age 9 according to Zusser, 1954) and fast growth performances, e.g. 67 cm, at age 4 (Nikolov, 1960).

Kara (1979), measuring large quantities of bonitos in the fish market of Istanbul, gave a perfect description of juvenile growth, from 20–25 cm in July to about 38–41 cm in June, based on twelve monthly l/f distributions. He also placed large fish, which locally have a different name from the young, in the range 50–90 cm LF (Figure 2).

The length distribution series (Figure 2) also shows the effect of temperature on growth: indeed from January to May (cold season) the sizes of young fish remain very similar and rapidly change from June onward. This effect is also clear in the second year of life.

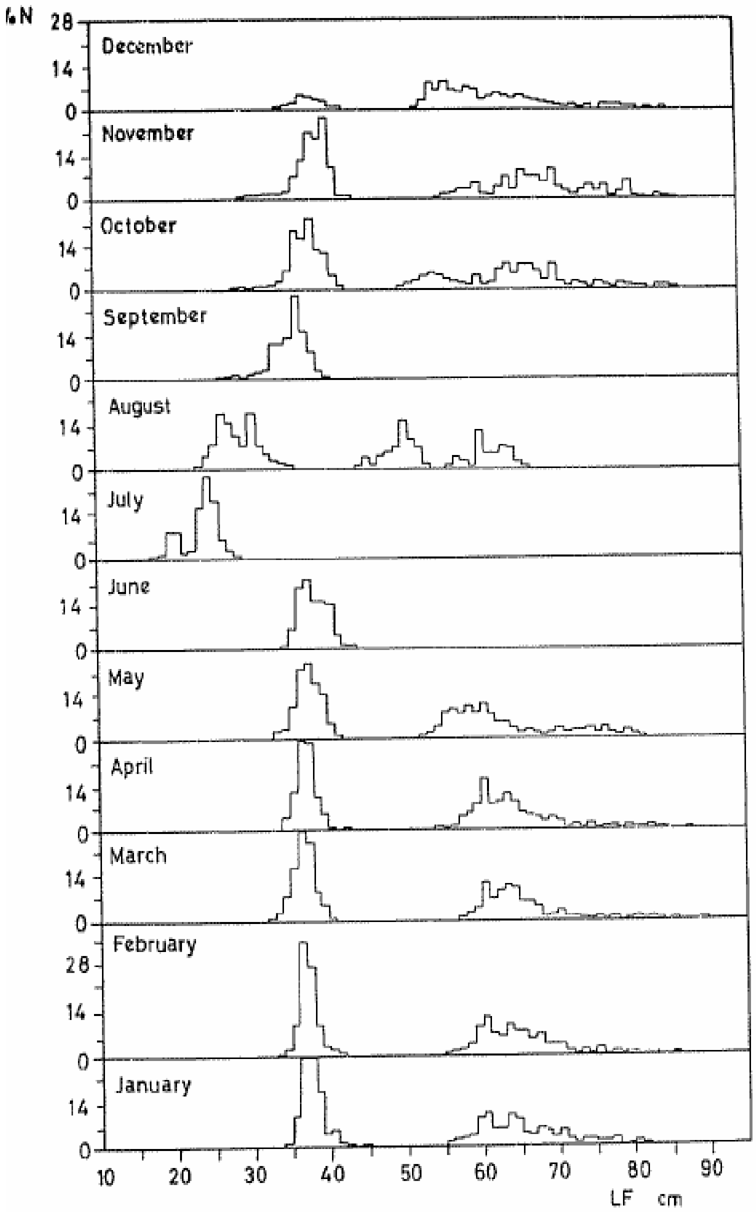


Figure 2 – Serial length/frequency distributions of *Sarda sarda* obtained during the year 1968 in the fish market of Istanbul (Kara, 1979). The set described includes 9 162 specimens

It is interesting to note that Rey *et al*. (1984) described the growth of 1982 cohort in the same way, on the basis of l/f distributions obtained in the tuna trap of Tarifa and Barbate, from 28 cm in September 1982 to about 40 cm FL in May and 44 cm in June 1983 (Figure 3). However, these authors overlooked this datum in respect of age reading by skeletal pieces (Table 3).

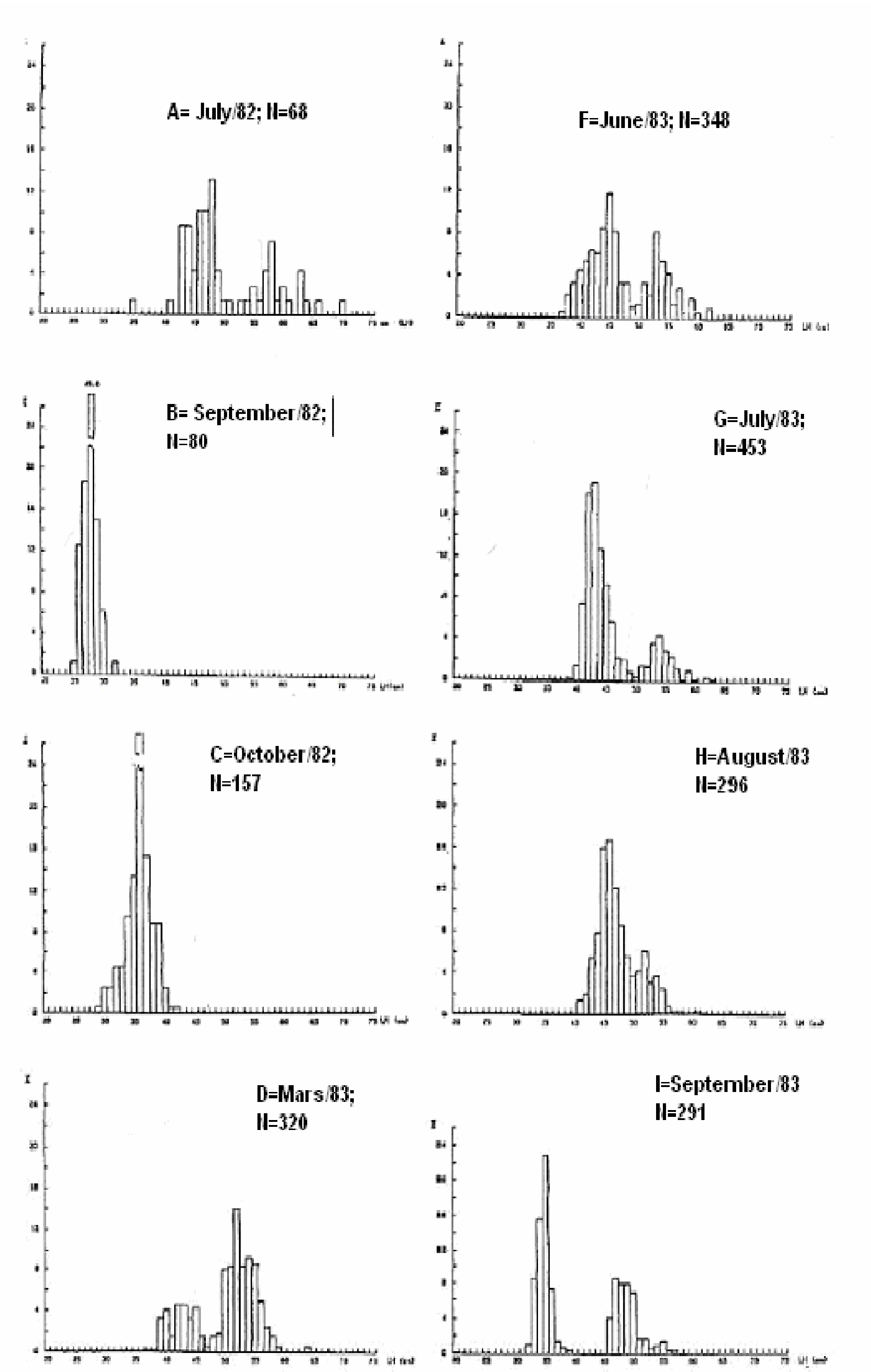


Figure 3 – Monthly length/frequency distributions of S. sarda in Spanish waters in 1982–83 (Rey, A lot and Ramos, 1984)

In the Western Mediterranean the range of sizes and, possibly, age groups derived by length/frequency distributions by means of material obtained in tuna traps, have recently been reported by Macias *et al*. (2006) (Figure 4) and Relini *et al*. (2007) (Figure 5).

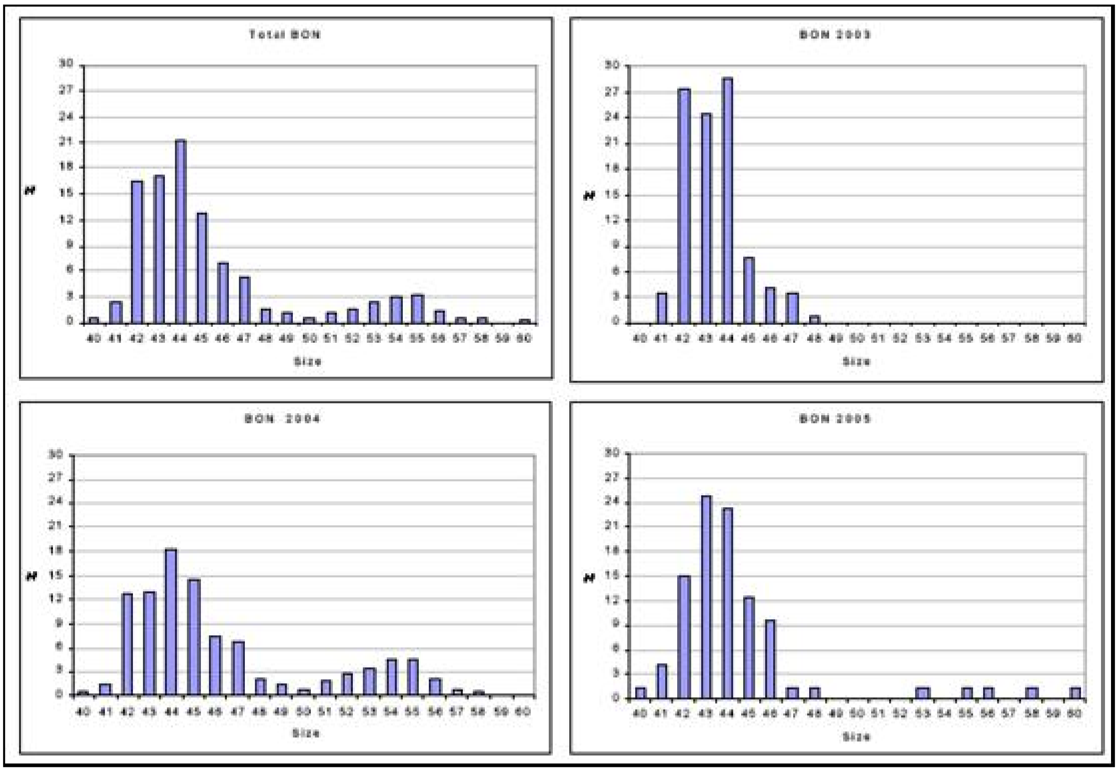


Figure 4 – Length/frequency distribution of *Sarda sarda* obtained in a tuna trap in Murcia (from Macias *et al*., 2006)

In Figure 4 the sizes were in the range 40.3–60 cm FL, with modal size at 44 cm in a first age group and 54–55 cm in a possible second age group. In the Ligurian sea a temporal series of size frequency distributions was derived from the small tuna trap of Camogli. The latter is a "tonnarella" i.e. a type of trap which some centuries ago was used in the Liguro-Provencal basin to target young bluefin of one to four years and is typical to this basin; this trap, the last surviving in the NW Mediterranean, is active from April to September and at present catches several coastal species but not bluefin tunas. Length/frequency distributions of bonitos show large fish in April, 51 cm FL and above, which in May disappear and are replaced by a younger fraction, 41–48 cm FL modal size. These grow during the summer months to 47–54 cm in September, i.e. becoming the group which in April of the following year will form the "large fish"; so the series describes the growth from age 1 to age 2.

It is interesting to note the analogies in size structures recorded in Murcia and in the Liguria Sea (Figures 4 and 5). They suggest common characteristics in the Western Mediterranean, reinforcing the hypothesis of a stock unit in this basin (Viñas, Alvarado Bremer and Pla, 2004; Orsi Relini *et al*., 2005), while a distinct stock unit might characterize the Aegean-Eastern Mediterranean. Indeed size at age 1 is larger in the Western (44 cm) than in the Eastern Mediterranean (41 cm), indicating a larger fish as well as the maximum sizes already reported in paragraph 2.1.0.

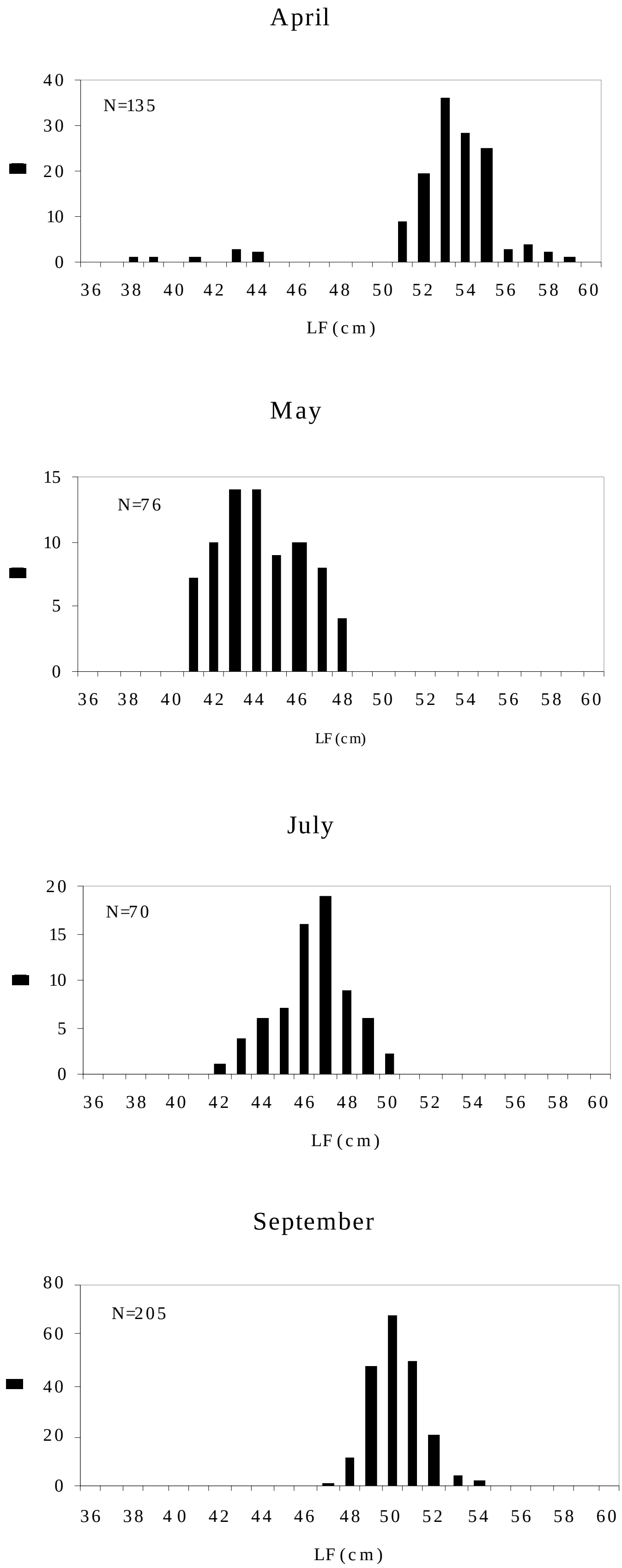


Figure 5 – Serial length/frequency distributions of *Sarda sarda* from the tuna trap of Camogli, Ligurian Sea (Relini, Calandri and Orsi Relini, 2007)

The range of sizes of Atantic bonito in the Adriatic is shown by the previously mentioned study on biometric characteristics (Franicevic *et al.*, 2005): such sizes do not have any time-frame indication. Among the 665 specimens obtained in the Croatian waters, 353 were females (53.08 percent), 285 were males (42.86 percent) and 27 (4.06 percent) were of undetermined sex. Fork lengths ranged between 33.0–67.0 cm with a mean of 42.2±6.077 cm and mode of 38.0 cm. Fork length in males ranged between 35.0–67.0 cm with a mean of 43.2±6.269 cm and mode of 40.0 cm. Fork length in females ranged between 33.0–64.5 cm with a mean of 41.8±5.889 cm and mode of 38.0 cm. The two dominant length groups were 38.5 cm and 39.0 cm. Males were more abundant in the 40.0 cm length group and females in the 38.0 cm length group (Figure 6).

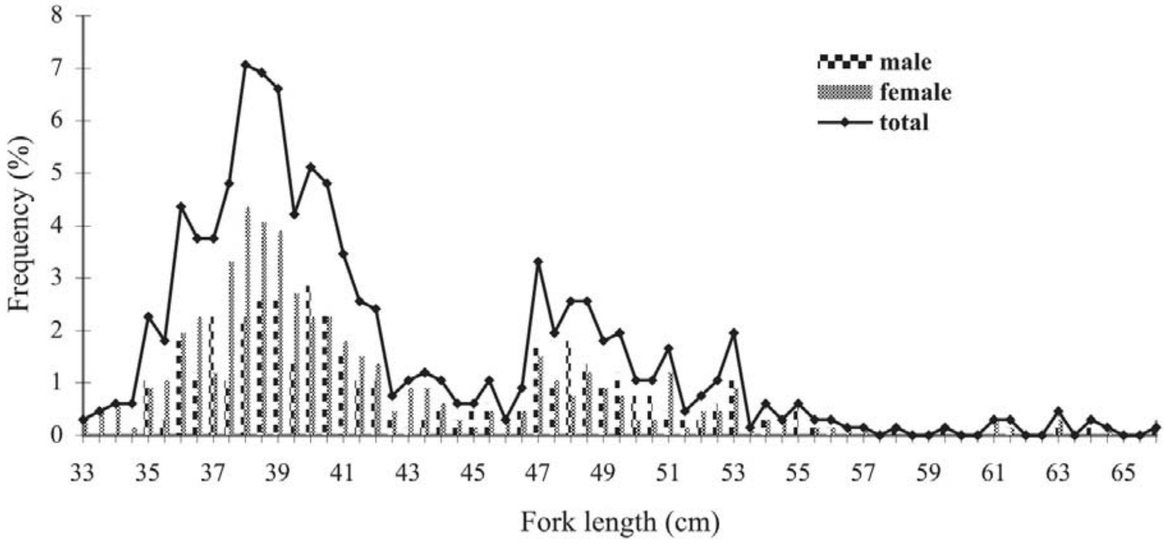


Figure 6 – Total lengths of Atlantic bonito, *Sarda sarda*, from the eastern mid Adriatic Sea (Franicevic *et al.*, 2005)

Somewhat different from the previous areas are the frequencies obtained by the hand line and gillnet fisheries in the Southern Tyrrhenian Sea and in the Straits of Sicily, where the statistical data have been collected thanks to the Italian programmes until 2000 and to the EC-DCR from 2001.

In the Southern Tyrrhenian Sea, where this fishery is mostly conducted by gillnets in spring-summer and troll lines and hand lines in spring and autumn, the main mode was the following: 34–37.9 cm in 1994, 38–39.9 cm in 1995, 40–41.9 in 1998, 38–41.9 in 1999, 52–53.9 in 2000, 40–41.9 in 2001, 50–51.9 in 2002, 48–49.9 in 2004, 40–41.9 in 2005, 52–53.9 in 2006 and 38–39.9 in 2007 (Figure 7, Di Natale and Mangano, in press).

The data collection from the southern Tyrrhenian Sea is one of the most extensive available in the Mediterranean Sea. The largest annual group (1999) was split in monthly graphs (Figure 8) and a modal progression is visible from August to November, while the winter and spring months show similar sizes; the apparent reduction of sizes in July and September may suggest movements of a subcohort of younger fish in the area. These figures can show more normal distribution when grouped bimonthly, showing a progressive increase of the mode by size over the year.

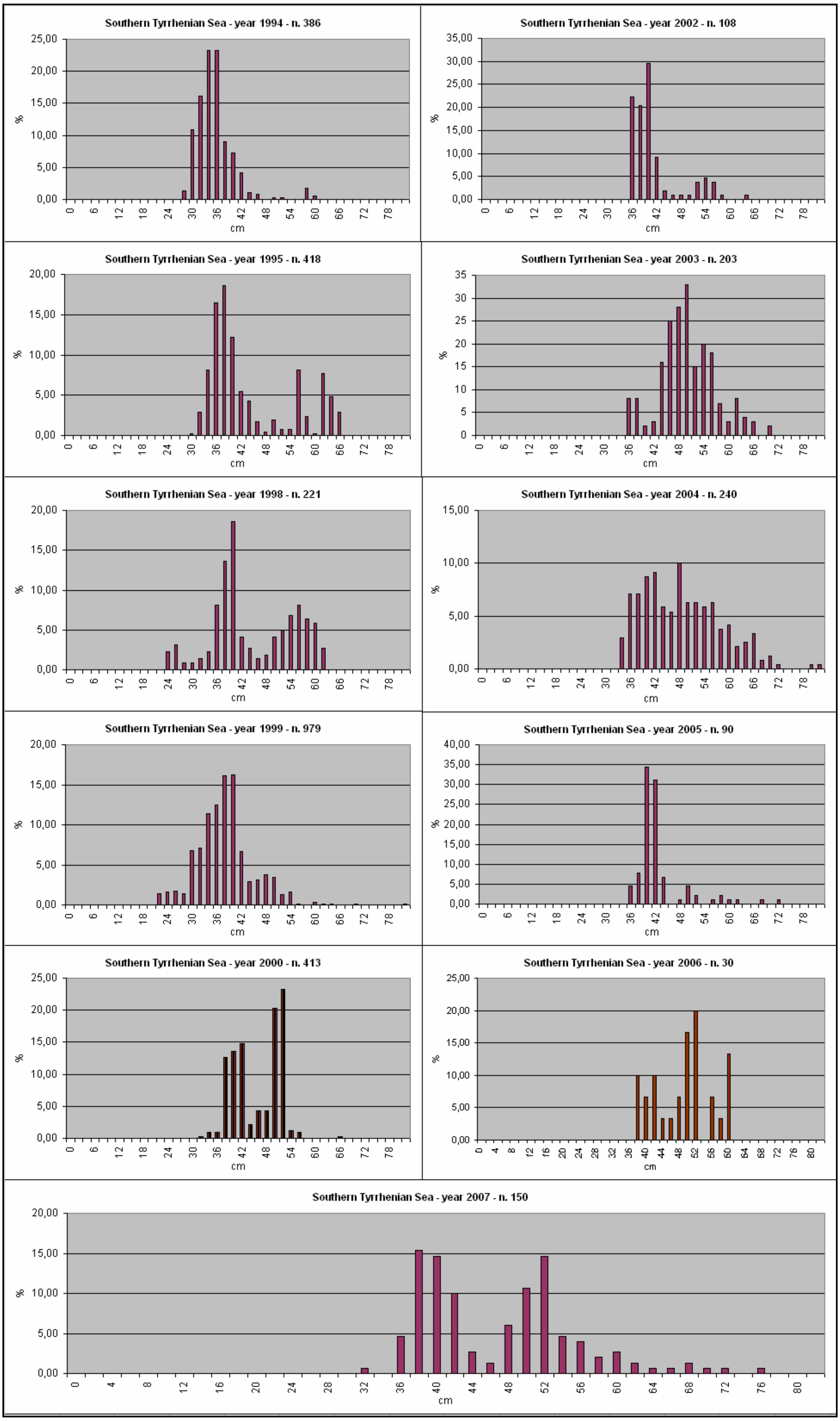


Figure 7 – Length/frequency distributions of *Sarda sarda* from the southern Tyrrhenian Sea from 1994 to 2007 (Di Natale and Mangano, in press)

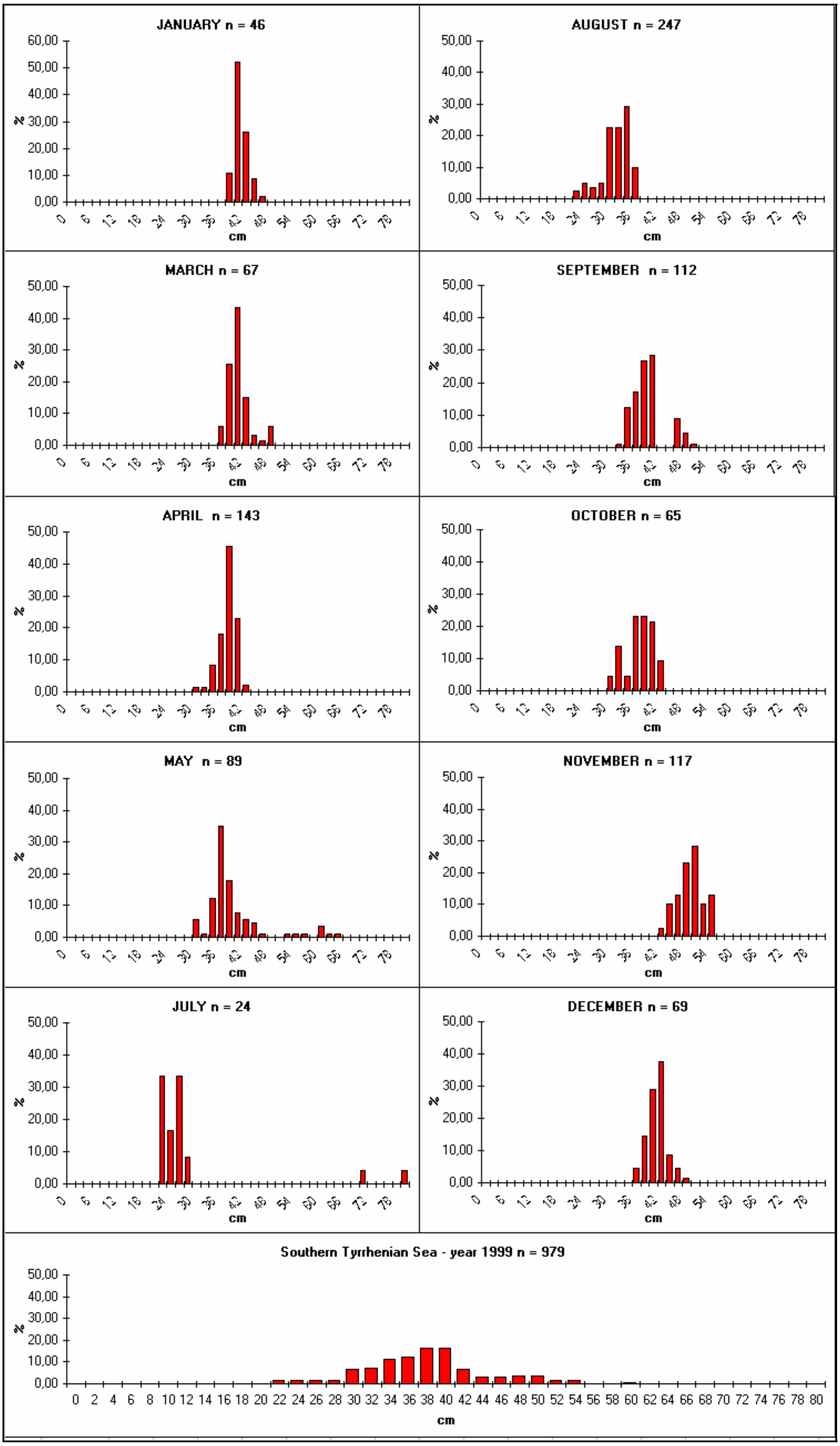


Figure 8 – Serial length/frequency distributions of *Sarda sarda* from southern Tyrrhenian Sea in 1999 (Di Natale and Mangano, in press)

In the Straits of Sicily, where this fishery is mostly conducted by troll lines and hand lines, the main annual mode was in the length class 46–47.9 cm in 2003, in the class 44–45.9 cm in 2004, in the classes 42–45.9 cm in 2005 and in the class 52–53.9 cm in 2006 (Figure 9, Di Natale and Mangano, in press). The polymodal structure in some years can be correlated to difference in time or presence. It is remarkable that the mode in 2004 was the same as reported in the tuna trap of Murcia, even though the length distribution was different.

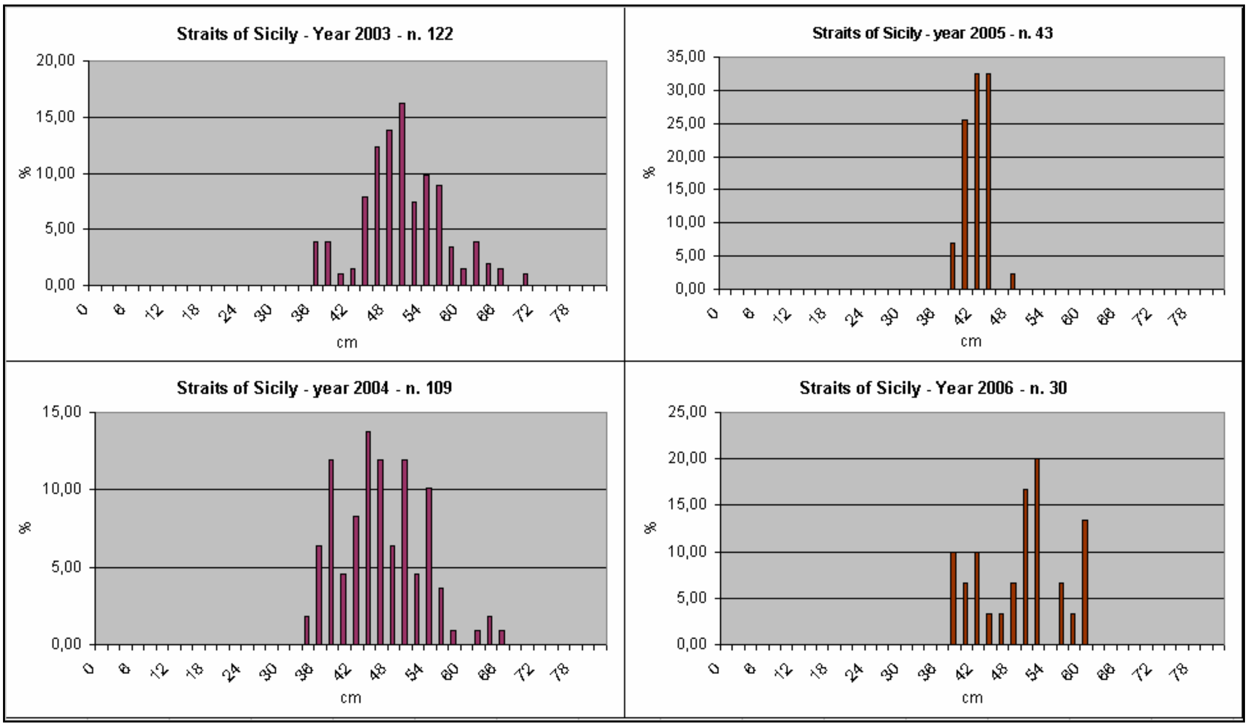


Figure 9 – Length/frequency distributions of *Sarda sarda* from the Straits of Sicily from 2003 to 2006 (Di Natale and Mangano, in press)

Some length data from the same area are reported for the southern part (Tunisian waters) by Hattour (2000). The size of these fish varies from 15 to 50 cm, with a mode at 36–38 cm class; this modal class represents 40.1 percent of the total sample (Figure 10).

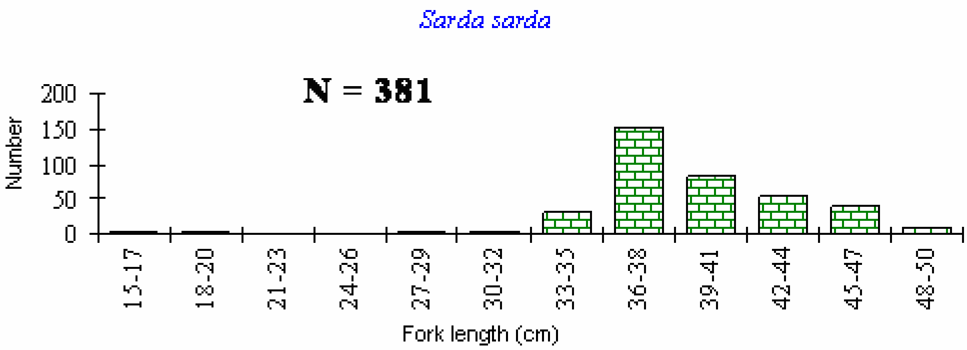


Figure 10 – Size distributions of Atlantic bonito in Tunisian water (Hattour, 2000)

Length data are also available from the Turkish areas (autumn-winter fishery). The length classes of the landed bonitos during the fishing seasons 2000 to 2002 were between 15.5 and 46.0 (28 ± 2.61, n=492) to 15.1–47.5 (31.2 ± 3.33, n=198) cm respectively. Two peak points in this group were observed; namely 26.4 ± 3.68 and 35.4 ± 3.57 cm respectively (Figure 11).

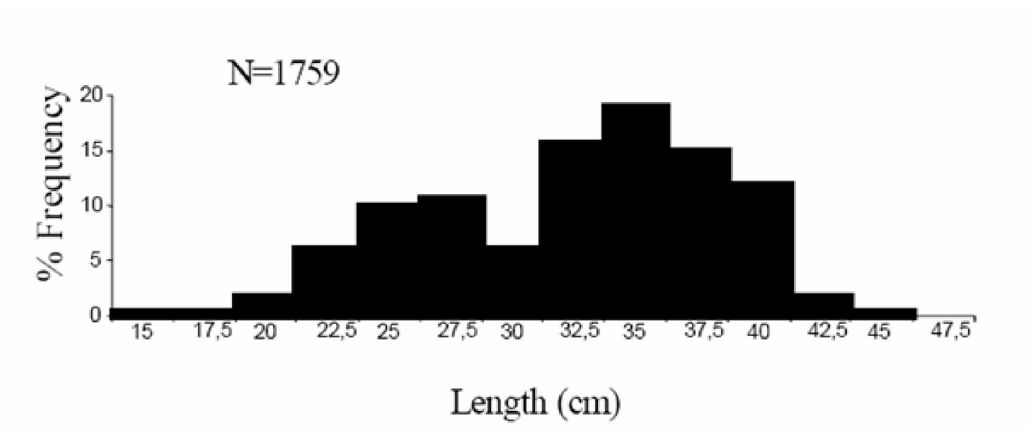


Figure 11 – Length frequency of *Sarda sarda* migrating to South Black Sea (Zengin, Karakulak and Oray, 2005)

The length distribution of Turkish catches by month in the fishing seasons 2000/01 and 2001/02 (August-February) is shown in Figure 12.

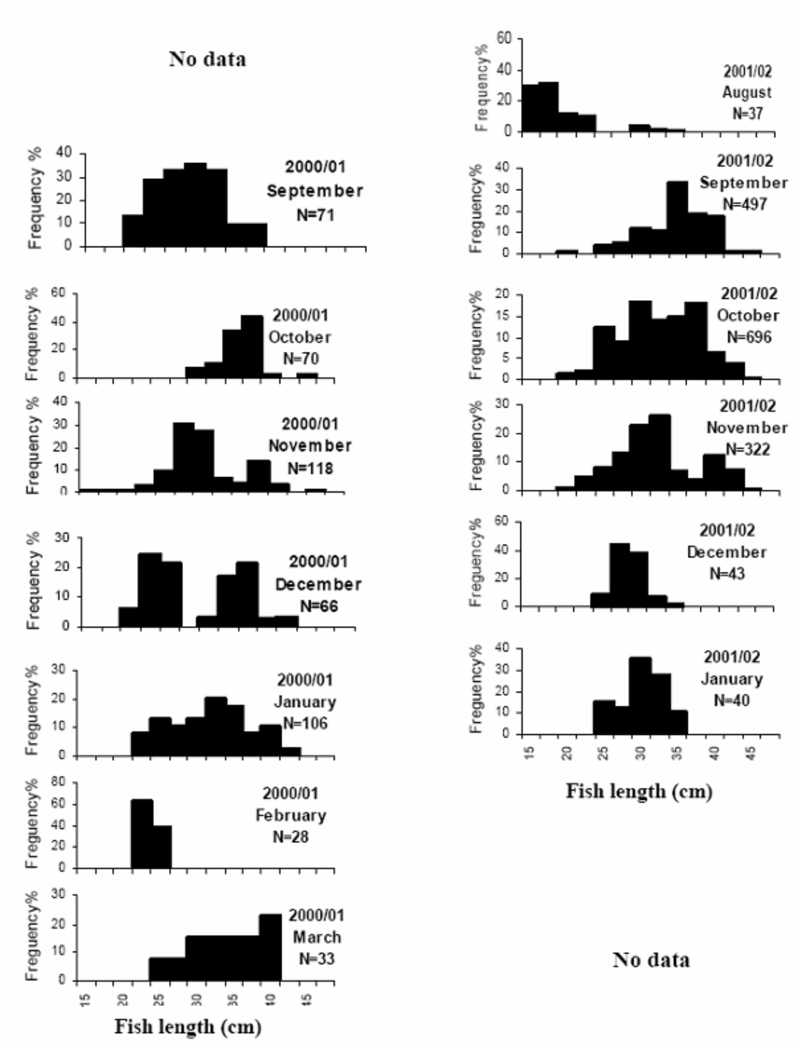


Figure12 – Length of *Sarda sarda* landed in Turkey in 2000/01 and 2001/02 (Zengin, Karakulak and Oray, 2005)

It is important to remark that, according to Rodriguez Roda (1966), the size distribution is similar by sex (see Figure 50b).

Where the **size at maturity and description of maturation** is concerned, Rey *et al.* (1984) described the maturation of *Sarda sarda* in terms of macroanatomy (Table 5).

Table 5 – Stages of maturity and related description of gonads (Rey *et al.*, 1984)

Stage of maturity	**Morphology of gonads**
Stage 1: undetermined	Gonads pinkish, in the shape of a narrow ribbon.
Stage 2: immature	Gonads thin but it is possible to determine sex. Female with enlarged and subcilindrical gonads; pinkish colour. Male with thin gonads in shape of ribbon; pinkish colour. **Testicular arteries easily visible in the median portion.**
Stage 3: beginning of maturation or recovering	Female have subcilindrical gonads, from dark pink to light red. Oocytes aren't yet visible. **Male with whitish gonads, with bigger size than in the female. Testicular arteries visible.**
Stage 4: maturation	Female with developed gonads; yellow orange colour. Oocytes visible. **Male with very developed gonads; whitish colour. It is possible to observe some spermatic fluids after incision.**
Stage 5: mature fishes – spawning	**Female with gonads at maximun developement, filling all the abdominal cavity. The oocytes, very large and translucent, are detached by simple pressure on the abdomen. Male with gonads at maximun development; it is possible to observe few red spots on the gonads surface. Seminal fluid spouts by simple pressure.**
Stage 6: post spawning	**Female gonadal aspect is different according to more or less recent deposition (ovary empty, very vascularized or contracted). Male have soft gonads, with the presence of scarce seminal fluid, owing recent deposition. Pinkish colour at the end of the deposition, whitish onward.**

Recently the female gonad maturation process has been described by Macias *et al.* (2005) on the basis of Gonadosomatic Indices and observations about the histological structure of the ovaries. Observed mature fishes were in the length range 41 to 47 cm FL.

Five different stages of ovarian activity are reported here:

a) Inactive females: the histological analysis indicates that the ovary contains no yolked oocytes and no atresic structures.

b) Active females: females were classified as active when the ovary contained yolked oocytes and there was no atresia or only minor atresia can be found. Active females were further classified into other stages according to additional criteria.

c) Ripening females (Maturing): Those females showing signs of sexual maturity (Yolked oocytes) but not signs of imminent spawn or signs of past spawns batches.

d) Pre-spawning females (Ripe): Those females showing signs of an imminent spawning like hydrated or nuclear migration phase oocytes but not postovulatory follicles or extended atresia. High density of oocytes in the ovary can be seen.

e) Spawning females: Those females whose ovaries present postovulatory follicles or imminent spawning signs like hydrated or migratory-nucleus oocytes. The histological analysis shows signs of past spawning (postovulatory follicles) and enough vitellogenic oocytes to complete more spawning.

f) Post-spawning females: Those females showing signs of past spawning (postovulatory follicles) but which do not have enough vitellogenic oocytes to complete more spawning. Extended atresia in vitellogenic oocytes. Low oocyte density in the ovary.

Rey *et al.* (1984) reported the **fecundity** of female *Sarda sarda* in the range of 47–71 cm FL, which showed between 220 000 to 1 500 000 eggs, while Macias *et al.* (2005) also provided **fecundity** estimates of six individuals in the range of 43–44 cm FL.

The **age of first maturity** in *Sarda sarda* in the Mediterranen Sea and Atlantic Morocco is reported at 38 cm in males and 39 cm in females (Rey *et a*l., 1984). In the Black Sea *Sarda sarda* reach first sexual maturity at the end of the first year (average length 39.0 cm) (Ivanov and Beverton 1985).

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