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THE GULF OF GABÈS (CENTRAL MEDITERRANEAN): NURSERY AREA FOR THE SANDBAR SHARK, *CARCHARHINUS PLUMBEUS* (NARDO, 1827) (CHONDRICHTHYES: CARCHARHINIDAE)

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ABSTRACT

The investigations conducted between 2001 and 2004 in the Gulf of Gabès (southern Tunisian waters, central Mediterranean) enabled the authors to collect fourteen pregnant females of the sandbar shark, Carcharhinus plumbeus *(Nardo, 1827), containing 96 near-term embryos and 120 neonates exhibiting an unhealed umbilical scar on dorsal surface. Total mass* versus *total length relationship in neonates was positively correlated. Concomitantly, juveniles are found throughout the year. These observations suggest that the species found favourable environmental conditions to develop and reproduce in the area. Pregnant females give birth in the area from March to July. A sustainable sandbar shark population has probably been established in the Gulf of Gabès, which could also be considered an important Mediterranean nursery area for the species.*

Key words: Chondrichthyes, *Carcharhinus plumbeus*, nursery area, Gulf of Gabès, Tunisia, central Mediterranean

GOLFO DI GABÈS (MEDITERRANEO CENTRALE): AREA DI NURSERY PER SQUALO GRIGIO *CARCHARHINUS PLUMBEUS* (NARDO, 1827) (CHONDRICHTHYES: CARCHARHINIDAE)

SINTESI

Le ricerche condotte tra il 2001 e il 2004 nel Golfo di Gabès (acque della Tunisia meridionale, Mediterraneo centrale) hanno permesso agli autori di raccogliere quattordici femmine gravide di squalo grigio, Carcharhinus plumbeus *(Nardo, 1827), contenenti 96 embrioni quasi del tutto sviluppati e 120 neonati con visibile sul dorso la cicatrice dovuta al parto. Una correlazione positiva è stata riscontrata tra la massa totale e la lunghezza totale degli individui appena nati. Stadi giovanili della specie sono stati trovati nell'area durante l'intero anno. Tali osservazioni suggeriscono che lo squalo grigio ha trovato condizioni ambientali favorevoli allo sviluppo e alla riproduzione in quest'area. Le femmine gravide portano a termine la gestazione nel periodo da marzo a luglio. Una popolazione sostenibile di squalo grigio si è probabilmente stabilita nel Golfo di Gabès, che può venir considerata un'area di nursery importante per la specie nel Mediterraneo.*

Parole chiave: Chondrichthyes, *Carcharhinus plumbeus*, area di nursery, Golfo di Gabès, Tunisia, Mediterraneo centrale

INTRODUCTION

The Gulf of Gabès is located in southern Tunisian waters and extends for some 750 km (Figs. 1, 2), with its waters considered to present sub-tropical affinities according to Postel (1956). Both wide and shallow continental shelves are topographically regular. The bottom slightly declines towards the sea, and 60 m depth occurs at 110 km away from the shore. In the Gulf of Gabès, the highest tides of up to two metres have been recorded, as have in fact been reported from elsewhere in the Mediterranean (Ben Othman, 1973).

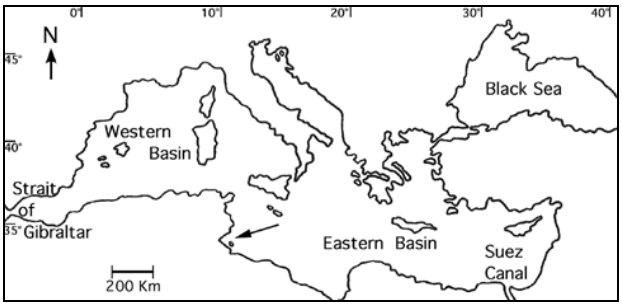

Fig. 1: Map of the Mediterranean Sea pointing at the Gulf of Gabès (black arrow).
Sl. 1: Zemljevid Sredozemskega morja z Gabeškim zalivom, označenim s črno puščico.

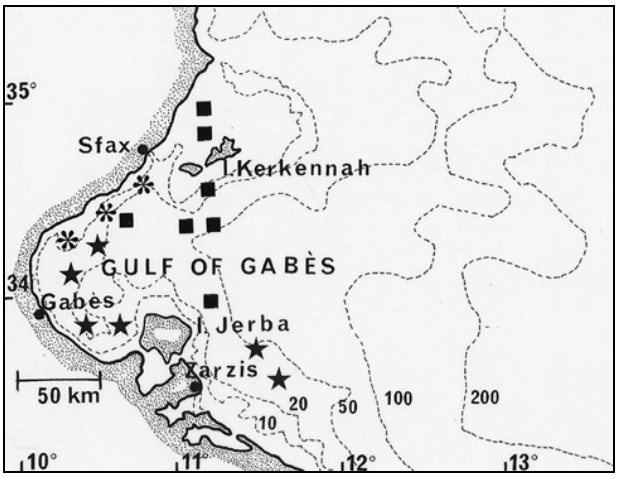

Fig. 2: Map of the Gulf of Gabès showing the capture sites of** Carcharhinus plumbeus **in the area. Legend: black stars – pregnant females, black asterisks – neonates, black squares - juveniles.
Sl. 2. Zemljevid Gabeškega zaliva z označenimi lokalitetami, kjer so bili ujeti sivi morski psi** Carcharhinus plumbeus**. Legenda: črne zvezde označujejo breje samice, črne zvezdice ravno skotene osebke, črni kvadrati pa mladiče.

The Gulf of Gabès is the most important Tunisian fishing area, comprising more than 50% of the local fishing fleet (Bradaï *et al.*, 1995). Throughout the year, commercial species are targeted, including sharks (Saïdi *et al.*, 2003), such as carcharhinids and smoothhounds of the genus *Mustelus*, especially between April and October.

Of the six carcharhinid species occurring in the Gulf of Gabès, *Carcharhinus plumbeus* is the first recorded and the most commonly landed throughout the year at the fishing sites of the area. Investigations conducted in the area during a five years period enabled us to collect several specimens and to find near-term females and small free-swimming specimens (Saïdi *et al.*, 2005). These new records provide additional data, which have improved our knowledge of the species in the area and confirmed previous papers in which the role of the Gulf of Gabès as the sharks' nursery area was suspected (Capapé, 1984; Bradaï *et al.*, 2002, 2004; Saïdi *et al.*, 2005).

MATERIAL AND METHODS

Data were collected from observations made at different fishing sites located along the Gulf of Gabès between 2001 and 2004. The specimens were caught by trawling, commercial gill-nets and longlines. Moreover, research surveys were conducted on board of the oceanographic trawler 'Hannibal' in May 2001, June 2002 and August 2003.

The specimens were measured to the nearest millimetre for total length (TL) following Bass *et al.* (1973) and weighed to the nearest kilogramme, when possible. The embryos removed from the uteri (see Fig. 3), and the smallest free-swimming specimens or neonates bearing an unhealed umbilical scar were measured to the nearest millimetre and weighed to the nearest gramme.

The onset of sexual maturity was determined in males from the condition and the length of claspers (CL). Bass *et al.* (1973), Stevens & Mc Loughlin (1991) and Watson & Smale (1998) have noted that the juveniles' claspers are short and flexible and that males are adult when claspers are rigid, elongated and calcified. The size of females at sexual maturity was determined from the condition of ovaries and the morphology of the reproductive tract following Natanson & Cailliet (1986), Capapé *et al.* (1990, 2002, 2005), Bridge *et al.* (1998) and Saïdi *et al.* (2005).

During the juvenile stage, the females ranging between 500 and 1640 mm TL had whitish ovaries, follicles of only microscopic size, membrane-like oviducts and inconspicuous oviducal glands. The collected juvenile females, ranging between 1640 and 1700 mm TL, had primarily white, translucent follicles, a well-differentiated genital duct and oviducal glands visible and slightly rounded (see Saïdi *et al.*, 2005).

A total of 712 females were captured in the Gulf of Gabès between January 2001 and May 2004. Of the 183 adult females observed, 18 only were non-eviscerated.

Tests for significance ($p < 0.05$) were performed by using ANOVA, Student *t*-test and the chi-square test. The linear regression was expressed in decimal logarithmic coordinates. Correlations were assessed by least-squares regression. In the relationship mass *vs.* total length, comparisons of curves were carried out by ANCOVA.

Length frequency data were collected from 120 neonates. Length frequency distributions were pooled by sex, at 10 mm intervals. The Kolmogorov-Smirnov two sample test was used to test significant difference in length frequencies.

RESULTS

Carcharhinus plumbeus is landed throughout the year at the fishing sites located in southern Tunisian waters (Bradaï *et al.*, 2002, 2004; Saïdi *et al.*, 2005). Of the 18 non-eviscerated adult females examined by us, 14 were pregnant females carrying near-term embryos (Tab. 1).

Ninety-six near-term embryos, 36 males and 60 females were collected (Tab. 1). The females TL ranged between 440 and 605 mm TL (mean: 530.8 mm ± 36.1), with mass between 479 and 1458 g (mean: 919.2 g ± 270.5). The males TL ranged between 430 and 590 mm (mean 525.2 mm ± 42.0), with mass between 391 and 1371 g (mean: 879.6 g ± 236.2).

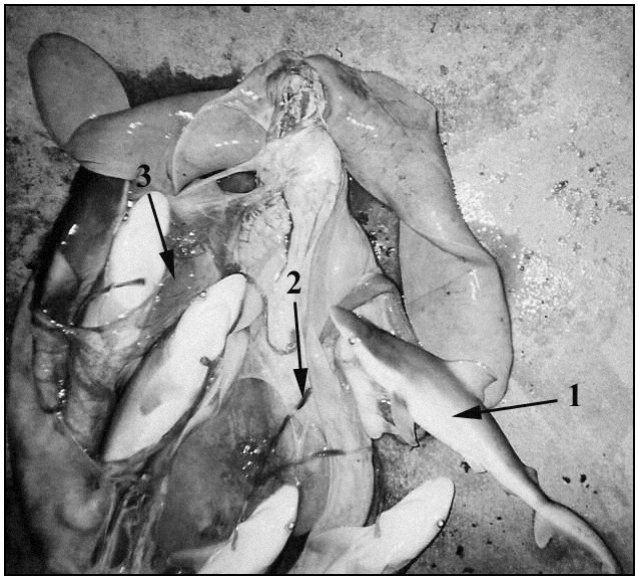

Fig. 3: Near-term embryos (1) removed from a pregnant female** C. plumbeus **showing umbilical cord (2) and uterine compartment (3).
Sl. 3: Že skoraj popolnoma razviti zarodki (1), odstranjeni iz breje samice** C. plumbeus **z dobro vidno popkovino (2) in maternično predelkom (3).

The relationship total mass *vs.* total length did not show significant differences between females and males. For females, the relationships are: log TM = 4.07 log TL – 8.15; r = 0.94; n = 60 and for males: log TM = 3.73 log TL – 7.21; r = 0.95; n = 32 (Fig. 4).

Tab. 1: Records of pregnant female** C. plumbeus **in the Gulf of Gabès with details on its uterine content.
Tab. 1: Podatki o breji samici** C. plumbeus **v Gabeškem zalivu, skupaj s podatki o vsebini samičine maternice.

Record	Month of catch	Female size (TL, mm)	Uterine content	Embryos number	Embryos size (TL, mm)	Embryos mass (g)
1	Mar	1910	Embryos	7	450-460	500-695
2	Mar	1970	Embryos	8	492-580	530-840
3	Mar	1990	Embryos	8	480-575	520-750
4	Apr	1795	Embryos	5	440-495	490-580
5	May	1720	Embryos	5	420-480	400-485
6	May	1775	Embryos	4	430-490	391-606
7	May	1895	Embryos	8	510-550	766-927
8	May	1790	Embryos	6	455-520	545-835
9	May	1980	Embryos	8	535-605	810-985
10	May	2000	Embryos	10	525-595	760-930
11	May	2100	Embryos	8	535-605	810-985
12	Jun	1770	Embryos	6	455-480	540-790
13	Jun	1800	Embryos	6	535-565	810-1050
14	Jul	1890	Embryos	7	570-625	990-1290
Total observed embryos				**96**	**-**	

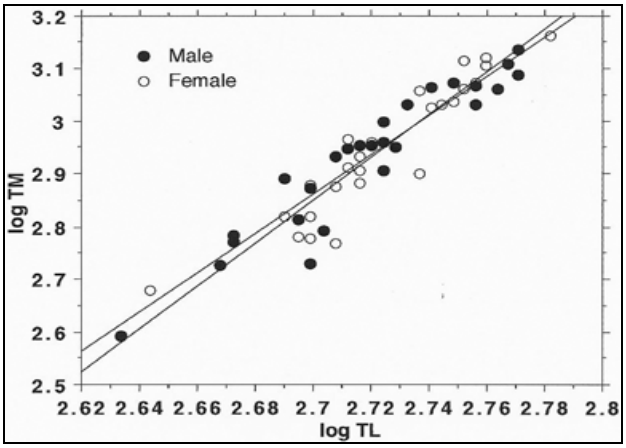

Fig. 4: Total Mass (TM)** vs. **Total Length (TL) relationship, expressed in logarithmic co-ordinates for male and female near-term embryos of** C. plumbeus**. TL was measured to the nearest mm and TM to the nearest gramme.
Sl. 4: Razmerje med celotno maso (TM) in celotno dolžino (TL), izraženo v logaritemskih koordinatah za že skoraj popolnoma razvite zarodke moškega in ženskega spola sivega morskega psa** C. plumbeus**. TL je bila izmerjena do najbližjega milimetra, TM do najbližjega grama.

Moreover, between August and September, 120 young free-swimming specimens, 62 females and 58 males, were observed; they exhibited an unhealed umbilical scar on the ventral surface, were neonates or at least born that year. The females TL ranged between 500 and 650 mm (mean: 590.44 mm ± 10.5), with mass between 851 and 1660 g (mean: 1264 g ± 115.7). The males TL ranged between 450 and 650 mm (mean: 600.0 mm ± 13.2), with mass between 400 and 1740 mm (mean: 1237.1 g ± 157.2).

In neonates as well as in embryos (cf. *supra*), the relationship total mass *versus* total length did not show significant differences between females and males. For females, the relationships are: log TM = 3.04 log TL - 5.33; r = 0.92; n = 62, and for males: log TM = 3.21 log TL - 5.90; r = 0.94; n = 58 (Fig. 5).

By contrast, the relationship total mass *versus* total length showed significant differences between near-term embryos (females + males) and neonates (females + males). For the former, the relationships are: log TM = 3.87 log TL - 7.59; r = 0.93; n = 96 and for the latter: log TM = 3.15 log TL - 5.57; r = 0.95; n = 120: F = 12.8; p = 0.005 (Fig. 6).

The overall length frequencies for neonates showed that practically similar sizes were reached by both sexes. The results of the Kolmogorov-Smirnov test indicate that the sexes were not sampled from populations with differing lengths distributions (p > 0.05); modal lengths were similar in both sexes (Fig. 7).

Near-term females were examined between March and July (see Table 1), but at the end of July this category of females disappeared from catches. These pregnant females were captured by demersal gill-nets (170 mm mesh size), at depths between 10 and 20 m in March and May, and at depths lesser than 10 meters from June to July, at sandy-muddy bottoms. These females were caught by special gill-nets, used only to capture sharks and locally known under the vernacular name of 'kallabia' (from *kalb' bhar*, which means shark in Arabic).

Soon after, neonates were captured from July to October (Fig. 8a), and no monthly significant differences were observed for both sexes (Fig. 8b). These neonates are usually captured at depths between 10 and 50 m, especially at sandy bottoms.

Tab. 2: Monthly collection of juvenile** C. plumbeus**, observed in the sample.
Tab. 2: Mesečna zbirka mladičev sivega morskega psa** C. plumbeus**, opazovanih v vzorcu.

Sex	Size (mm)	Months												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Males	700-900	2	3	13	23	30	19	14	12	2	25	9	5	157
	900-1100	4	2	3	7	3	20	22	23	3	5	3	5	100
	1100-1300	0	0	1	1	0	16	10	4	2	1	0	0	35
	1300-1500	0	0	0	2	10	7	0	3	0	1	0	0	23
	Total	6	5	17	33	43	62	46	42	7	32	12	10	315
Females	700-900	3	2	20	36	44	35	24	12	1	31	13	8	229
	900-1100	1	3	0	1	9	23	30	33	2	5	5	5	117
	1100-1300	1	0	0	3	2	12	10	18	0	1	1	0	48
	1300-1400	0	0	0	2	5	3	3	8	0	1	0	0	22
	1500-1700	0	0	0	4	14	6	0	1	3	0	1	0	29
	Total	5	5	20	46	74	79	67	72	6	38	20	13	445
General total		**11**	**10**	**37**	**79**	**117**	**141**	**113**	**114**	**13**	**70**	**32**	**23**	**760**

Furthermore, as juveniles are caught throughout the year, catches are significantly higher from May to September due to fact that sharks are targeted during this period of the year (Tab. 2).

DISCUSSION

Since the first record of *C. plumbeus* in the Gulf of Gabès, reported by Pietschmann (1906), a literature review shows, to date, a permanent occurrence of the species in the Gulf of Gabès (Postel, 1952, 1956, 1958; Quignard & Capapé, 1971; Capapé, 1974, 1984; Bradaï *et al.*, 2002, 2004; Saïdi *et al.*, 2005).

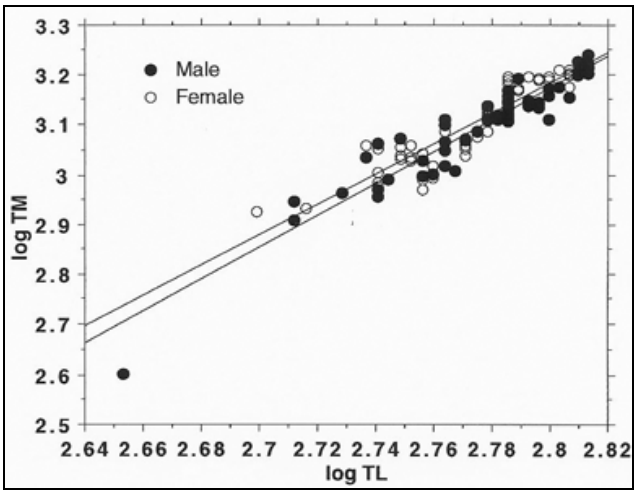

Fig. 5: Total Mass (TM)** vs. **Total Length (TL) relationship, expressed in logarithmic co-ordinates for male and female neonates of** C. plumbeus**. TL was measured to the nearest mm and TM to the nearest gramme.
Sl. 5: Razmerje med celotno maso (TM) in celotno dolžino (TL), izraženo v logaritemskih koordinatah za ravno skotene osebke moškega in ženskega spola sivega morskega psa** C. plumbeus**. TL je bila izmerjena do najbližjega milimetra, TM do najbližjega grama.

Moreover, Capapé (1989) showed that despite the competition pressure between carcharhinids in the Gulf of Gabès (see above Capapé *et al.*, 2003b, 2004), *C. plumbeus* is abundantly and commonly landed at local fishing sites (Saïdi *et al.*, 2003, 2005). These observations suggested that a sandbar shark population was definitively established in the Gulf of Gabès, and consequently, the occurrence of nurseries in the area. This occurrence has previously been suspected in preliminary data provided by Capapé (1974, 1984) who reported captures of both pregnant females and neonates *C. plumbeus* in southern Tunisian waters.

The results presented in this article showed a relative abundance of near-term females at depths between 10 and 20 m, lower than those usually reported for capture of large specimens (Quignard & Capapé, 1971). In these shallow waters, known to be energetically rich and the object of intensive fishery activities all year round (Bradaï *et al.*, 1995; Bradaï, 2000), neonates were concomitantly captured. So, pregnant females could obviously find sufficient resources to nourish embryos throughout gestation, which is also the case as far as neonates growing rapidly during the first weeks of their lives are concerned.

However, growth of embryos during gestation is significantly higher than in neonates (see Fig. 8). These observations firstly confirm the mother's role during embryonic development in viviparous placental species (Capapé *et al.*, 2003a, 2004; Saïdi *et al.*, 2005) and secondly that neonates were not probably experimented feeders during the first period of their extra-uterine lives, at least (Capapé *et al.*, 2003a).

Captures of near-term females occurred between March and July, and after this period no near-term females were captured in the area. These disappearance is immediately followed by captures of neonates between July and October. This suggests that *post-partum* females migrated off-shore towards deeper areas. Similar patterns were reported by Springer (1960, 1967) for *C. plumbeus*, from the Atlantic coast of the United States of America and the Gulf of Mexico.

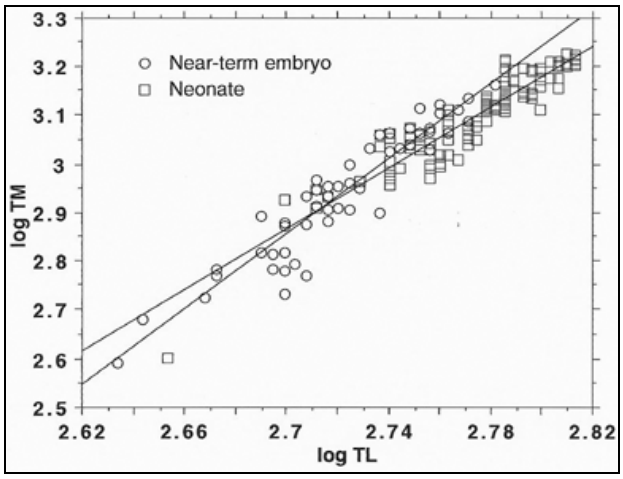

Fig. 6: Total Mass (TM)** vs. **Total Length (TL) relationship, expressed in logarithmic co-ordinates for near-term embryos and for neonates** C. plumbeus**. TL was measured to the nearest mm and TM to the nearest gramme.
Sl. 6: Razmerje med celotno maso (TM) in celotno dolžino (TL), izraženo v logaritemskih koordinatah za skoraj popolnoma razvite zarodke in ravno skotene osebke sivega morskega psa** C. plumbeus**. TL je bila izmerjena do najbližjega milimetra, TM do najbližjega grama.

Nevertheless, a competition pressure with sympatric carcharhinid species and predation by larger sharks have been considerably reduced (Capapé, 1989; Capapé *et al.*, 2003b; Bradaï *et al.*, 2002, 2004), although they could not be totally excluded (see Heupel & Hueter, 2002; Castro, 1993).

Moreover, the permanent and historical occurrence of juveniles in the Gulf of Gabès (see Table 1) showed that *C. plumbeus* reproduced and developed in the area (see Saïdi *et al.*, 2005). This suggests that the Gulf of Gabès could be a nursery area for the sandbar shark.

In the northern Mediterranean (Adriatic Sea), juvenile specimens have been collected by Lipej *et al.* (2000), whereas Costantini & Affronte (2003) recorded neonates bearing umbilical scars and ranging between 465 and 688 cm TL. Moreover, a pregnant female, 2 m TL and 70 kg in mass, was recorded in the same area by Travaglini (1982, in Costantini & Affronte, 2003). On the basis of these findings, Costantini & Affronte (2003) suggested 'that the northern Adriatic Sea is an important nursery ground for *C. plumbeus*'. In 2003, when de Sabata *et al.* (2003) observed juveniles *C. plumbeus* and pregnant females during their diving off Turkey, a female was filmed giving birth. De Sabata *et al.* (2003) suggested that bay in Turkey was the single known nursery site to date as far as the Mediterranean Sea is concerned. However, the mere presence of neonates or near-term pregnant females could not be considered sufficient parameters in order to delineate this area a shark nursery (see Castro, 1993).

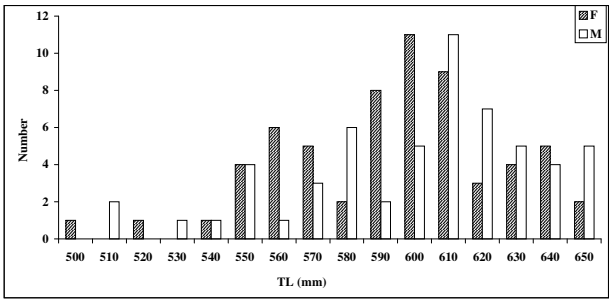

Fig. 7: Length distribution of male and female neonates of** C. plumbeus**, examined during the present study.
Sl. 7: Dolžine osebkov obeh spolov ravno skotenih mladičev sivih morskih psov** C. plumbeus**, preučevanih med pričujočo raziskavo.

Ben-Tuvia (1966) and Garrick (1982) considered the Red Sea a source for some Mediterranean carcharhinids, such as *C. brevipinna* and *C. limbatus*. However, they did not comment on the occurrence of *C. plumbeus*. The sandbar shark is relatively abundant in the Red Sea (Gohar & Mazhar, 1964; Baranes & Wendling, 1981), and as pregnant females were found in the area (Baranes & Wendling, 1981), migrations through the Suez Canal remain doubtful. Furthermore, Hemida *et al.* (2002) and Hemida & Capapé (2003) reported on recent occurrence of carcharhinid species off the Algerian coast, originating from the eastern tropical Atlantic and entering the Mediterranean Sea through the Strait of Gibraltar, and among them sandbar sharks were mainly recorded. An Atlantic source for *C. plumbeus* requires further confirmation, but as these records were recorded only recently, they cannot explain the early abundance of *C. plumbeus* in the Gulf of Gabès. By contrast, a Tunisian source for sandbar sharks for other Mediterranean areas, such as the Adriatic Sea, remains a suitable hypothesis.

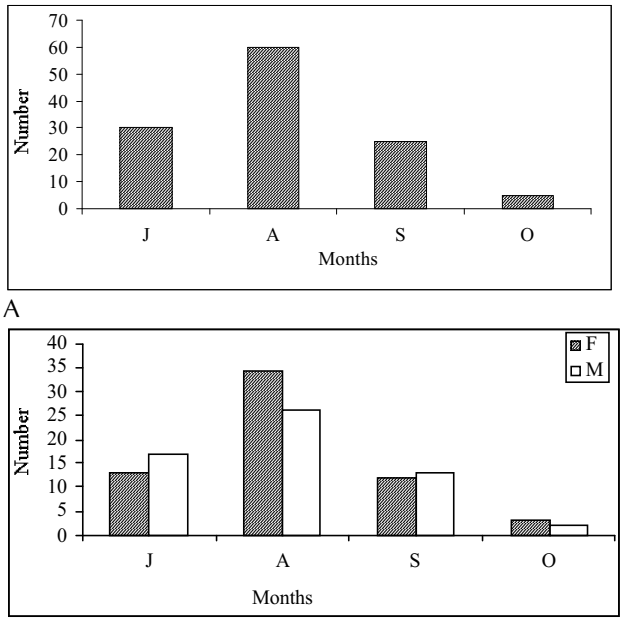

Fig. 8: (A) Monthly distribution of neonate** C. plumbeus**, examined during the present study between July and October. (B) Monthly distribution of** C. plumbeus **male and female neonates, examined during the present study between July and October.
Sl. 8: (A) Mesečna razporeditev ravno skotenih osebkov sivih morskih psov** C. plumbeus**, preučevanih med julijem in oktobrom. (B) Mesečna razporeditev ravno skotenih osebkov moškega in ženskega spola sivih morskih psov** C. plumbeus**, preučevanih med julijem in oktobrom.

GABEŠKI ZALIV (SREDNJE SREDOZEMLJE): RAZMNOŽEVALNO OKOLJE SIVEGA MORSKEGA PSA *CARCHARHINUS PLUMBEUS* (NARDO, 1827) (CHONDRICHTHYES: CARCHARHINIDAE)

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POVZETEK

Raziskave, opravljene med letoma 2001 in 2004 v Gabeškem zalivu (Tunizija, srednje Sredozemlje), so avtorjem omogočile, da so preučili štirinajst brejih samic sivega morskega psa Carcharhinus plumbeus *(Nardo, 1827) s 96 že skoraj popolnoma razvitimi zarodki in 120 ravno skotenimi osebki, s poporodno brazgotino na hrbtu. Razmerje med celotno maso in celotno dolžino pri skotenih osebkih je bilo premosorazmerno. Mladiče sivega morskega psa je v celotnem območju mogoče najti ob vsakem letnem času. Ta opažanja dajejo misliti, da je vrsta našla ustrezne okoljske razmere za razvoj in razmnoževanje v teh vodah. Breje samice tu rojevajo med marcem in julijem. Gabeški zaliv je območje, v katerem se je najbrž razvila trajnostna populacija sivega morskega psa, in bi utegnil biti tudi pomembno sredozemsko razmnoževalno okolje za to vrsto.*

Ključne besede: Chondrichthyes, *Carcharhinus plumbeus*, razmnoževalno okolje, Gabeški zaliv, tunizijska obala, srednje Sredozemlje

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