ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
41 (2): 71-78, 2000

UDC: 597(262.2)
Original scientific paper

Biological aspects of the Gulper shark, *Centrophorus granulosus* (BLOCH and SCHNEIDER, 1801), from the Mediterranean coast of Israel

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Biological aspects of the gulper shark Centrophorus granulosus *were studied from September 1982 to November 1992 along the Mediterranean coast of Israel at depths of 200-1400 m. Males dominated the intermediate depths (550-800 m), while at the shallowest depths (200-400 m) the population consisted mainly of females. Gravid females had only one embryo or a single large egg. Stomach contents revealed that the diet of* C. granulosus *consisted mainly of cephalopods and meso- to bathypelagic fishes. The ratio of body length to the percentage of liver weight from total body weight increased from ca. 15% in small specimens to ca. 25% in large specimens. A rational fishing exploitation policy, which recommends concentrating fishery on male rich depths, is presented.*

Key words: *Centrophorus granulosus*, bathymetric distribution, sex ratio, diet, fishery

INTRODUCTION

Until the mid-1970's Israel fisheries exploited mainly shallow and upper continental shelf grounds no deeper than 200 m. In the 1980's the local trawler, searching for new fishing grounds, started to explore deeper waters up to 400 m. The most common shark in the newly exploited area (200-400 m) is the gulper shark *Centrophorus granulosus* (BLOCH and SCHNEIDER, 1801).

Species of the genus *Centrophorus* MÜLLER & HENLE, 1837 are demersal medium sized sharks, inhabiting the continental shelf on both sides of the Atlantic Ocean, the western Indian Ocean and possibly also in Japan (BIGELOW and SCHROEDER, 1957). Characteristically they have spines in both dorsal fins, upper jaw teeth shaped considerably different than lower jaw teeth and sharply pointed inner corner of pectoral fins. Of the seven nominal species in this genera recognized worldwide, only *C. granulosus* occurs in the Mediterranean. Another species, *Centrophorus uyato* (RAFINESQUE, 1810), often cited in literature as inhabiting the Mediterranean, is a junior synonym (CAPAPÉ, 1985; MUNOZ-CHAPULI and RAMOS, 1989) of *C. granulosus*.

The occurrence of this shark was first recorded in the Levant by PISANTY (1981), who identified it as an important component for the bottom hook-and-line experimental catch at depths of 200-400 m. GILAT and GELMAN (1984) added information to its bathymetrical and diurnal distribution, gathered from an underwater photographic survey. Very few biological studies have been done on sharks in the Levant, due to some extent to the low esteem given them in local markets. However *C. granulosus* is considered to have potential commercial value (CASTRO *et al.*, 1994) because of the considerable amount of squalene present in their large liver; squalene constitutes up to 63% of the liver oil in the closely related species *C. squamosus* (ANONYMOUS, 1989). Squalene is an important ingredient in the pharmaceutical and cosmetic industries.

The present study examines the biology of *C. granulosus* and also presents a recommended rational management of deepwater fishery in the region.

MATERIAL AND METHODS

Specimens of *C. granulosus* were sampled from September 1982 to November 1992. Sharks from depths of 200-1400 m were collected by bottom hook-and-line, using MUSTARD KIRBY ringed and tuna circled hooks no. 6-9 (for details, see GOLANI, 1987). At depths of 200-400 m, additional specimens were obtained from commercial trawlers using nets of 40-48 mm mesh size.

Total length (*TL*) of 178 specimens was measured to the nearest 1.0 mm and the sex was recorded. Of these sharks, a total of 96 specimens were brought to the laboratory for further study. Fifty-two specimens were weighed to the nearest 1.0 g and then dissected. The liver was weighed to the nearest 1.0 g. Stomachs of most specimens were empty, probably due to either feeding periodicity or food regurgitation upon capture. In cases of non-empty stomachs, the contents were identified to the lowest possible taxa.

Oviducts of females were dissected. Egg and embryo size (to the nearest 0.1 mm) and weight (to the nearest 0.1 g) were recorded. Females were considered gravid if an embryo was found or an egg whose diameter exceeded 80 mm and weight of 60 g.

RESULTS

Total length of 178 specimens was measured in the present study and found to range from 395 to 967 mm.

Size composition correlated with depth: smaller specimens inhabit deeper waters. The bathymetrical distribution also showed a clear trend of sexual distribution (Fig. 1). At the deepest station of 1400 m, only immature individuals were found, with an equal sex ratio. Males were

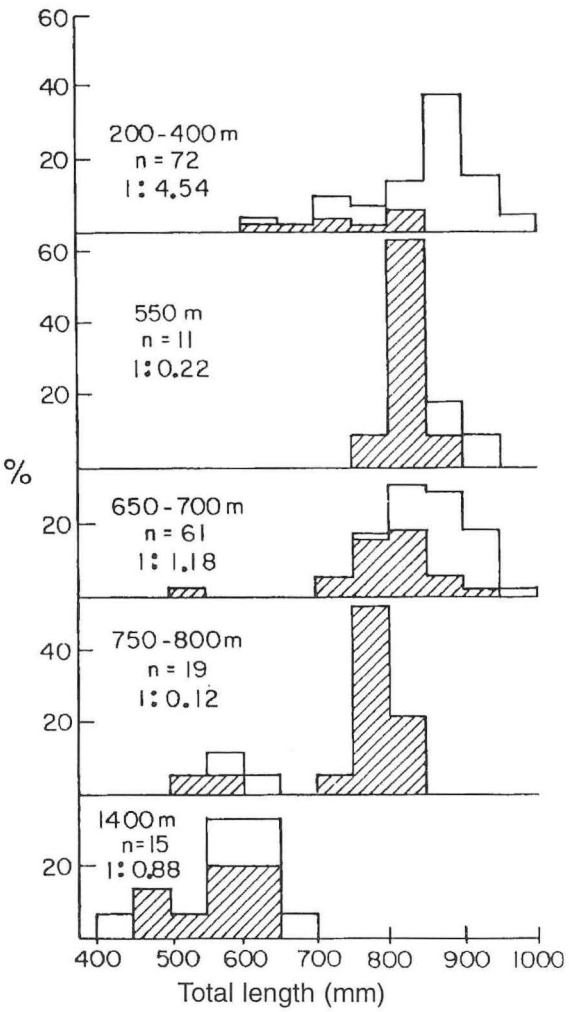

Fig. 1. Length frequencies of males (hatched) and females (open) and their sex ratio by depth

Table 1. Data on Centrophorus granulosus *specimens studied in the laboratory. T - trawl, H - hook & line, (im) - immature*

Date	Method	Depth (m)	Females		Males	
			No. of specimens (gravid)	size range (mm-TL)	No. of specimens (running)	Size range (mm-TL)
20 May 83	T	300	7 (2)	751-880	-	-
20 July 83	T	250-300	14 (5)	699-919	-	-
25 July 83	T	250-300	4 (0)	804-895	-	-
22 Oct. 84	T	250-300	13 (13)	795-950	1	740
25-26 June 85	H	1400	4 (im)	550-629	2(im)	535-657
Sept. 85	T	250-300	5 (5)	837-925	-	-
21 Jan. 87	H	1300	- -	- -	2(im)	475-568
	H	800	- -	- -	4(4)	740-770
22 June 87	H	550	2 (2)	820-830	9(7)	710-825
9-10 Dec. 87	H	700	- -	- -	4(4)	770-819
30 Nov. 89	H	1330	- -	- -	2(im)	435-600
1 Dec. 89	H	550	2	840-881	3	748-798
24-26 Apr. 92	H	750	3	780-920	2	760-775
		1400	1 (im)	605		
6 Dec. 92	H	700	1 (im)	600	8	550-810
	H	1400	1 (im)	590-620	2(im)	510-545

dominant in intermediate depths (550-800 m). Among 91 individuals caught at these depths, we found 37 females and 54 males. This is a significant male-biased sex ratio (P=0.046 using the exact binomial test). This result was obtained despite an isolated one-time collection on 26 April 1991, when a group of 19 females was encountered at depth of 700 m. At depths of 200-400 m females outnumber males. Among 72 individuals caught at these depths we found 59 females and only 13 males. This is a highly significant female-biased sex ratio (P=1.9 x10^{-8} using the binomial test).

Gravid females were found throughout the year at depths of 550 m and shallower. Running males were found in much deeper water (as deep as 800 m) (Table 1). However, their number was too low to enable determining of seasonal appearance.

The smallest gravid female was 795 mm and the smallest mature male was 725 mm. Each gravid female had a single embryo or a single large egg, usually with several small immature eggs (diameter 10-30 mm).

The largest embryo, collected at September 1985 at 250 m from a 855 mm female had a total length of 336 mm and weight of 162.2 g. It was attached to a yolk sac with diameter of close to 80 mm and weighed 53.8 g. The specimen was deposited in the Hebrew University Fish Collection (Catalogue number HUJ 17315)

The smallest juvenile was a male (395 mm total length) caught on 25 April 1992 by hook-and-line at 1400 mm (HUJ 15076).

Table 2 presents a list of the organisms found in *C. granulosus* stomachs. It was impossible to obtain quantitative data since most prey organisms were in progressive stages of being digested; in most cases only remnants were

Table 2. List of organisms found in stomachs of Centrophorus granulosus *from the coast of Israel + - a single occurrence, ++ - multiple occurrence*

Crustacea	Isopod	+
Mollusca	Cephalopods	++
Fish	*Sudis hylina*	++
	Merluccius merluccius	+
	Dentex macrophthalmus	+
	Unidentified fishes	++

found. The weight-length relationship was found to be:

$$W = 9.886 \times 10^{-7} TL^{3.604} \quad (N=52)$$

Where: W is weight in g and TL is total length in mm.

No significant differences between males and females were observed (Fig. 2).

The ratio between body length and the percentage of liver weight from body weight increased linearly and found to be:

$$L = 0.021 \times TL + 5.332 \quad (R = 0.519) \quad (N=52)$$

where L is percentage of liver weight from body weight and TL is total length in mm.

No difference between males and females was found (Fig. 3).

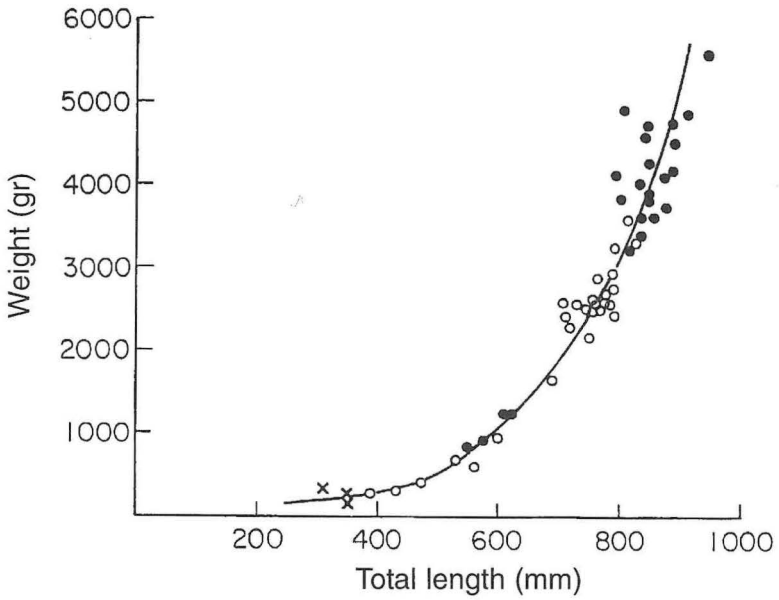

Fig. 2. Length weight relationship of Centrophorus granulosus; o - *males,* • - *females, x - embryos*

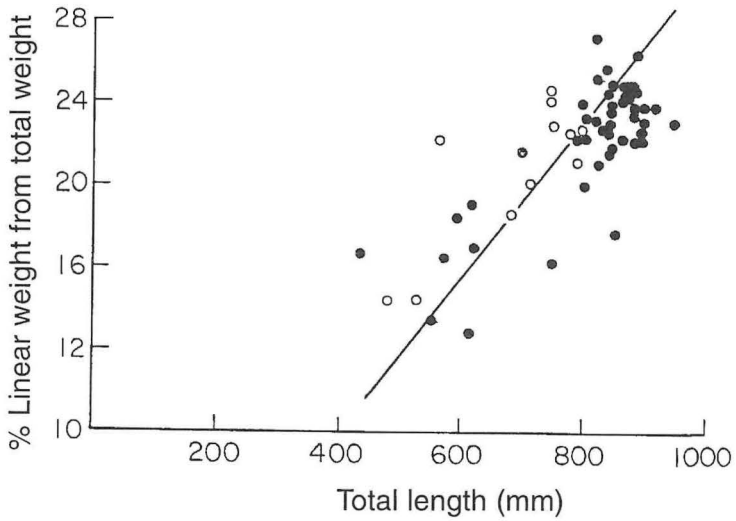

Fig. 3. Relationships between total weight and liver weight (present as percentage of total weight) in Centrophorus granulosus; o - *males,* • - *females*

DISCUSSION

Segregation by size and sex is a well-documented phenomenon among Elasmobranchi (BULLIS, 1976; SMALE, 1991). Most studies showing bathymetrical distribution in sharks demonstrated a repeating pattern of young individuals inhabiting a shallower habitat and descending to deeper water upon maturation (BIGELOW and SCHROEDER, 1948; BULLIS, 1967; SMALE, 1991; TURSI, *et al.*, 1993). The present study revealed an opposite trend in *C. granulosus*. Based on this study's finding, we constructed a life history sequence of bathymetrical distribution. Birth takes place in the deepest zone, following descent of the females. The reason that no mature females were captured at the 1400 m depth may be the result of their brief sojourn in that area; in addition, the females probably cease to feed during this period and therefore are not susceptible to capture by hook-and-line. Migration to upper habitats seems to occur in unisexual groups, with males dominating the intermediate zone. However, the occurrence of some mature females in the intermediate depths leaves open the question of location of copulation. There are several possibilities: copulation may occur in intermediate or shallow waters or in both. Females may descend to male-rich habitat for copulation (where females were found to be mature but non-gravid). However, the number of males in the shallow sector is probably adequate to permit copulation with the larger number of females. The latter possibility may present a potential advantage to the species since in this case only the superior males succeed to reach copulation. The bruises reported by PISANTY and GOLANI (1995) on male specimens could result from male-to-male rivalry.

Paucity of males in the shallow habitat may also contribute to reduction of intraspecific trophic competition. The high trophic pressure in the higher sector and prevention of cannibalism, as proposed by SPRINGER (1967), may be another reason that new-born are delivered in deepwater.

At which size *C. granulosus* reaches sexual maturity cannot be determined accurately from the available data. Anyhow, there appears to be a rapid increase in weight upon maturation as found in other sharks, by EBERT (1986a,b) in *Notorynchus cepedianus* PERON, 1807 and *Hexanchus griseus* (BONNATERRE, 1788). The smallest mature male (725 mm *TL*) and female (795 mm *TL*) observed in this study corresponded to the onset of rapid weight increase in both sexes (Fig. 2).

The size of full term embryos found in this study matches the range of (30-40 cm) given by COMPAGNO (1984). The largest embryo measured (336 mm *TL*) was probably not full-term, since it was still attached to a considerably large yolk sac. The smallest free swimming specimen (395 mm *TL*) was within the range given by COMPAGNO (1984).

Despite the most stomachs being empty, the limited data on feeding habits strongly suggested that *C. granulosus* is primarily a bottom dwelling feeder.

The finding of some remnants of meso - to bathypelagic fish such as *Sudis hyalina* and cephalopods "beaks" suggested that *C. granulosus* occasionally utilizes a wider tropic niche. Our findings concur with the findings of CAPAPÉ (1985, 1989) from Tunisia.

The ratio of liver weight to total body weight (hepatosomatic index) was found to increase with total body length. This phenomenon was noted by CORNER *et al.* (1969) and BALDRIDGE (1970), in their studies of the liver buoyancy of deepwater sharks. Since the liver is the major body organ effecting buoyancy in sharks, this increase may be explained by merely hydrostatic reasons. CAPAPÉ (1985) suggested the existence of a correlation between the hepatosomatic index and reproductive stages, but we did not find such a correlation in our study.

The low reproductive rate of *C. granulosus* suggests the need for a rational exploitation policy. Exploitation of the shallow female-rich sector is liable to decimate the stock by capturing mainly gravid females, threatening progeny and future reproduction. The sexual segregation

by depth found in this study allows the establishment of recommended guidelines by which fishery is redirected to concentrate efforts on the depths dominated by males (550-800 m). The relative disadvantage of deeper water fishing and catching smaller males (with smaller livers) will be offset by the valuable deepwater groupers (*Polyprion americanus* and *Epinephelus haifensis*) and hake (*Merluccius merluccius*) which are abundant at these depths (PISANTY and GOLANI 1995).

ACKNOWLEDGEMENTS

We would like to thank M. BEN-YAMI for critically reading the manuscript, O. SONIN and A. GELMAN for assisting the collection of the sharks, U. MOTRO for the help with the statistics, B. APPELBAUM for editorial assistance, H. SELIGMAN for translation of relevant literature in French and D. DAROM for the graphics.

REFRENCES

ANONYMOUS. 1989. Market opportunities for sharks liver oil. Austr. Fish. (Nov.), 8-9.

BALDRIDGE, H.D. Jr. 1970. Sinking factors and average densities of Florida sharks as functions of liver buoyancy. Copeia, 1970, 744-754.

BIGELOW, H.B. and W.C. SCHROEDER. 1948. Sharks. In: Fishes of the Western North Atlantic. Mem. Sears Found. Marine Res., I Part II, pp. 59-576.

BIGELOW, H.B. and W.C. SCHROEDER. 1957. A study of the sharks of the suborder Squaloidea. Bull. Mus. Comp. Zool. Harv. Univ., 117(1) : 150 pp.

BULLIS, H.R. 1967. Depth segregation and distribution of sex-maturity groups in the Marbled Catshark *Galeus area*. In: Gilbert, P.W., P.F. Mathewson and D.P. Rall (Editors.). Sharks, skates and Rays. Johns Hopkins Press, Baltimore, pp. 141-149.

CAPAPÉ, C. 1985. Nouvelle description de *Centrophorus granulosus* (Schneider, 1801) (Pisces, Squalidae). Données sur la biologie de la reproduction et le régime alimentaire des spécimens des côtes tunisiennes. Bull. Inst. natn. scient. tech. Océnogr. Pêche Salambô, 12: 97-141.

CAPAPÉ, C. 1989. Les selaciens des côtes méditerranéennes: aspects generaux de leur écologie et exemples de peuplements. Océanis, 15(3): 309-331.

CASTRO, J.I., C.M. WOODLEY and R.L. BRUDEK. 1999. A preliminary evaluation of the status of sharks species. FAO Fish. Techn. Paper, No. 380. FAO, Rome, 72 pp.

COMPAGNO, L.J.V. 1984. FAO species catalogue. Vol. 4. Sharks of the World. An annotated and illustrated catalogue of shark species known to date. Part I. Hexanchiformes to Lamniformes. FAO Fisheries Synopsis, 125. FAO of the UN, Rome, pp. 1-249.

CORNER, E.D.S., E.J. DENTON and G.R. FORSTER. 1969. On the buoyancy of some deep-sea sharks. Proc. Roy. Soc. London B, 171: 415-429.

EBERT, D.A. 1986a. Aspects of the biology of Hexanchid sharks along the California coast. In: Uyeno T., R. Arai, T. Taniuchi and K. Matsuura (Editors.). Proc. 2nd Intern. Conf. Indo-Pacific Fishes. Ichth. Soc. Japan, Tokyo, pp. 437-449.

EBERT, D.A. 1986b. Biological aspects of the sixgill shark *Hexanchus griseus*. Copeia, 1986 : 131-134.

GILAT, E. and A. GELMAN. 1984. On the sharks and fishes observed using underwater photography during a deep-water cruise in the eastern Mediterranean. Fish. Res., 2: 257-271.

GOLANI, D. 1987. On deep-water sharks caught off the Mediterranean coast of Israel. Isr. J. Zool., 34: 23-31.

HORNUNG, H., M.D. KROM, Y. COHEN and M. BERNARD. 1993. Trace metal content in deep-water sharks from the eastern Mediterranean Sea. Mar. Biol., 115: 331-338.

MUNOZ-CHAPULI, R. and F. RAMOS. 1989. Review of the *Centrophorus* sharks (Elasmobranchii, Squalidae) of the eastern Atlantic. Cybium, 12: 65-81.

PISANTY, S. 1981. Deep water longline fishing trials off the Israeli Coast. Fish. Fishbreeding Isr., 16(3): 17-23. (Hebrew, Engl. Abstr.).

PISANTY, S. and D. GOLANI. 1995. Vertical distribution of demersal fish on the continental slope of Israel. In: Armantrout, N.B. (Editor). Condition of the World aquatic habits. Proc. World Fish. Cong. Theme 1. Oxford & IBH Pub. Com., New Delhi, pp. 386-395.

SMALE, M.J. 1991. Occurrence and feeding of three shark species *Carcharhinus brachyurus, C. obscrurus* and *Sphyrna zygaena* on the eastern Cape coast of South Africa. South Afr. J. Mar. Sci., 11: 31-42.

SPRINGER, S. 1967. Social organization of sharks population. In: Gilbert, P.W., R.F. Matheuson and D.P. Rall (Editors.). Sharks, Skates and Rays. John Hopkins Press, Baltimore, pp. 149-174.

TURSI, A., G. D'ONGHIA , A. MATARRESE and G. PISCITELLI. 1933. Observation on population biology of the Blackmouth catshark *Galeus melastomus* (Chondrichthyes, Scyliorhinidae) in the Ionian Sea. Cybium, 17: 187-196.

Accepted: 21 August 2000

Biološki aspekti psa kostelja dubljinca, *Centrophorus granulosus* (BLOCH i SCHNEIDER, 1801) u mediteranskim obalnim vodama Izraela

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SAŽETAK

U radu je prikazana studija bioloških aspekata psa kostelja dubljinca, *Centrophorus granulosus* (BLOCH i SCHNEIDER, 1801) u mediteranskim obalnim vodama Izraela na dubini između 200 - 1400 metara, u periodu od rujna 1982. g. do studenog 1992. godine. Mužjaci su predvladavali na dubini između 550 do 800 m, dok je na dubini između 200 i 400 m populacija bila sastavljena pretežno od ženki. Gravidne ženke imale su samo jedan embrion ili jedno veliko jaje. Sadržaj želudaca upućuje na to da se hrana *C. granulosus* sastoji od cefalopoda i mezo- do batipelagijskih riba. Omjer duljine tijela i postotka težine jetre u odnosu na ukupnu težinu je u porastu i to od otprilike 15% kod malih primjeraka pa do otprilike 25% kod većih primjeraka.

Politika racionalnog ribarstvenog iskorištavanja preporuča ribolov mužjaka na većim dubinama.