



ECOLOGY OF THE MOTTLED GROUPER (*MYCTEROPERCA RUBRA*) IN THE EASTERN MEDITERRANEAN

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Abstract: The mottled grouper, *Mycteroperca rubra*, is the most abundant grouper in the shallow rocky habitats <40m depth along the eastern Mediterranean. A study carried out from May 1999 to July 2002 revealed that the fish reaches a length of over 83.5 cm (total length), which is the longest reported for *M. rubra*. The growth equation was found to be total length(cm) = 15.192*Ln(age(years))+31.108. The size and growth rate of this fish found along the Israeli coast contradict the "Levantine nanism theory".

M. rubra is a protogenic hermaphrodite. Females become sexually mature at the age of 2+ years and the youngest male found was 3+ years. The oldest female and male examined during the research were 13+ and 19+ years respectively.

The breeding season along the Israeli coast is from February-March to the end of May. During this period monthly aggregations of up to 500 fish were observed at traditional sites. Estimated female fecundity was found to be ca. 570,000 oocytes X weight (kg).

Fish comprised 98% of the stomach content of the mottled groupers. A single prey, *Siganus spp.*, made up ca. 68% of the food biomass. We suggest that the success of the mottled grouper in establishing a large population in the eastern Mediterranean has been mainly due to the opening of the Suez Canal that enabled the invasion of Indo Pacific *Siganus spp.*, which is its main food source.

Key words: *Mycteroperca rubra*, eastern Mediterranean, fish reproduction, sex reversal, diet.

Introduction

The eastern Mediterranean is a changing environment. It is strongly affected by the continuous invasion of Indo-Pacific biota through the Suez Canal (Golani et al. 2002), and by the intensive fishery that has led to a reduction in the size reached by large species (personal communications). There has also been a recent increase of >2°C to over 30°C (MEDAR/MEDATLAS II 2004) in surface water temperatures during summer time due to global warming. The fishes of Red Sea origin comprise about 50% of the fish biomass in the rocky littoral zone and of the fishery catches along the Israeli coast (Golani & Ben Tuvia 1993, Goren & Galil 2001). One of the fish groups most strongly affected by

these changes is that of the groupers (Serranidae, Epinephelinae) of the rocky habitats, which represent the top predators in this habitat. The groupers have been affected by both changes in the availability of various food components and the sharp increase in fishing pressure during the last four decades, following expansion of spear-hunting supported by SCUBA gear.

Three out of the nine groupers known from the Mediterranean (Heemstra & Randall 1993) inhabit the rocky habitats along the Israeli coast: *Epinephelus costae*, *Epinephelus marginatus* and *Mycteroperca rubra*. The most abundant (about 50% of grouper biomass in shallow rocky habitats - Aronov 2002) but the least known among them is the mottled grouper *M. rubra*. This

species is found along the coasts of the eastern Atlantic Ocean (from Portugal to Angola), North Africa and the eastern Mediterranean but is absent from the northwest Mediterranean (Heemstra & Randal 1993). The mottled grouper appears to be common in Senegal but rare along the North African coast (Heemstra & Randal 1993, Siau & Bouain 1994).

The only published information regarding the biology of *M. rubra* to date is that of Siau & Bouain (1994), who examined nine fish and reported that in Tunisia the fish spawn toward the end of spring and that onset of sexual maturity takes place at a fish size of 27-32 cm (standard length).

The present work aimed at a comprehensive study of various biological aspects such as growth rate, sex ratio, sex reversal, reproduction and diet, in order to better understand the impact of the anthropogenic changes on the three rock groupers along the Israeli coast. It was carried out from May 1999 to July 2002. Here we present the findings regarding the most common but least known of the groupers - *M. rubra*

Materials and Methods

The research was carried out at seven different rocky sites (one of them - Rosh Hanikra- is a nature reserve). The other sites were (in north-south direction): Acre, Haifa, Ma'agan Michael, Givat Olga, Netanya and Tel Aviv.

Visual observations, photography and sampling (spear fishing) were carried out approximately every two weeks (weather permitting). During the research period 205 mottled groupers, total weight ca. 400 kg, were sampled. As the fish were found to be sensitive to the presence of SCUBA divers, the underwater work was mostly carried out by free dive to a maximum depth of 18 m.

Total length (TL) and standard length (SL) of the fish were measured to the nearest 0.5 cm. The fish were weighed to an accuracy of 2 gr. The gonads were weighed to the nearest 0.001 g and preserved in 4% formaldehyde. Stomachs were removed,

weighed and preserved in 4% formaldehyde solution. Otoliths were removed and kept in small paper envelopes.

Determination of sex and sexual maturity

Sex was determined through examination of microscopic slides prepared from each preserved gonad. The slides were prepared using standard eosin-hemotoxilin procedure.

Fish were determined as female when the gonads contained oocytes only (Figures 1A-D); as male when mature gonads contained testicular tissue only (Figure 1F); and as a transitional form when ovarian and testicular tissues were found together (Figure 1E).

Two parameters were used in order to identify the stage of ovarian maturity: the gonado-somatic index (GSI); and status of the most mature oocytes found in the ovary. The oocytes were classified following Marino et al., (2001) for *E. marginatus*. Females were determined as sexually mature whenever oocyte stage was higher than LV. (Figures 1C, D)

Fecundity

Fecundity was determined as the potential number of oocytes that could be spawned during one spawning season. Following a preliminary study in which we found that oocytes at various stages are evenly distributed in all parts of the ovary (in both lobes), thirty fragments of ovaries were taken from ten females of different sizes (3 from each) and weighed to the nearest 0.0001 gr. The number of oocytes in each fragment was counted. The average weight of an egg was calculated for each fragment (*Wei*). The fecundity of a female was calculated as $F = Wo / (\sum_1^3 Wei / 3)$ where *Wo* = total ovary weight.

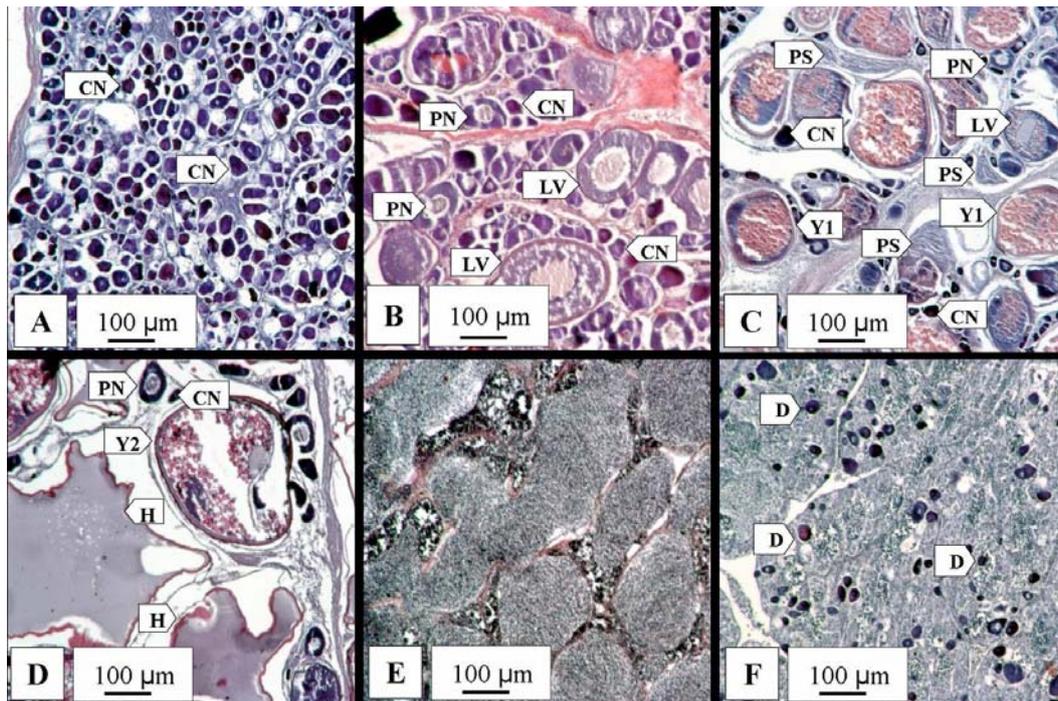


Figure 1. A: Resting \ immature ovary. B: Early stage of maturity. C: Mature ovary. D: Ready to spawn. E: sex-reversing gonad (female to male). F: Testis. CN (chromatin-nucleolus), PN (peri-nucleolus), LV (lipid vesicle), Y-1/2/3 (yolk), H (hydrated)



Figure 2. A. Otolith of *M. rubra* 3+ years old.



Figure 2. B. Otolith of *M. rubra* 11+ years old.

Age and growth

The number of annual rings in the otoliths determined age. The otoliths were fixed in wax, and a slice 0.7 mm thick was then cut widthwise through the center of the otolith using a low-speed diamond blade saw. The slices were examined under X6.7 magnification. Examples of otoliths of fish aged 3+ (Figure 2A) and 11+ are shown in Figure 2.

Length-weight relationship was determined by the formula $W=aL^b$.

The maximal age, length and weight were determined from our samples, although larger fish had been noted during the visual observations.

Food analysis

The stomach content of each sampled grouper was examined. Fish found in the stomach were weighed to the nearest 0.1gr and identified to the species level in most cases. Invertebrates were identified to class level and weighed to the nearest 0.1gr.

Results

Occurrence

M. rubra was found to be the most abundant grouper in the rocky habitat along the Israeli coast (< 50% of groupers sampled during the research). The fish were usually observed at depths of 1 to 35 m., swimming about 0.1-5 m. above the rocky bottom, solitarily or in small groups (up to 10 fish). During the reproduction season groups of ca. 500 individuals were observed. When disturbed, the mottled groupers sought refuge in caves and holes. The fish were active during daytime and slept after sunset in caves and holes. Specimens smaller than 10 cm were observed in the shallow rocky habitats (<10 m.) throughout most of the year.

Relationship between length to weight, age and sex

Weight-length relationship was found to be $W=0.007*TL^{3.1353}$, where W=weight (gr.) (Figure 3). The largest specimen observed during this study was 83.3 cm (7.4 kg). Observations suggested that *M. rubra* can reach a size of 95 cm (TL).

Age-length relationship was found to be $L(TL)=15.192*Ln(age)+31.108$, N= 148 (Figure 4).

The length distribution of the sexed fish is shown in Figure 5. All fish under 35 cm were females. The shortest mature female found during our research was 35 cm (TL). The shortest male was 42 cm (TL). The longest male and female found in this study were 75.5 cm. and 74.0 cm. respectively. Sex-changing specimens were found between the lengths of 40 to 65 cm.

Sex-age relationship

The age distribution of the sexed fish is shown in Figure 6. The youngest and older mature females were found to be in the age groups of 2+ years and 13+ years respectively. The youngest and oldest males were found to be 3+ and 19+ years respectively. The overlap in age among the sexes was within the range of 3+ to 13+ years. Sex- changing specimens were found between the ages of 2+ and 6+. Figure 6 also shows a steep decrease in the number of groupers older than 4+ belonging to both sexes.

Average age and length for males and females sampled during the present study are presented in Table I. Sex-changing specimens were included in the male group. The differences in the age and the length of males and females were found to be significant using the Mann Whitney U test.

Reproduction

Seasonality

Determination of the reproduction period was achieved through a combination of the stage of the oocytes and the GSI.

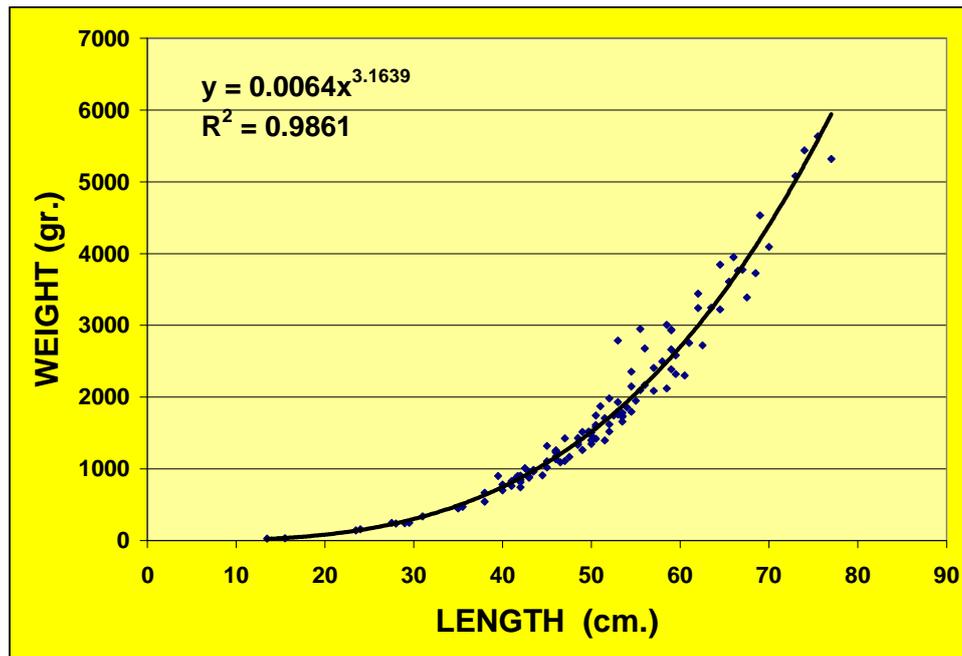


Figure 3. Weight length relationship of *M. rubra* (N=113).

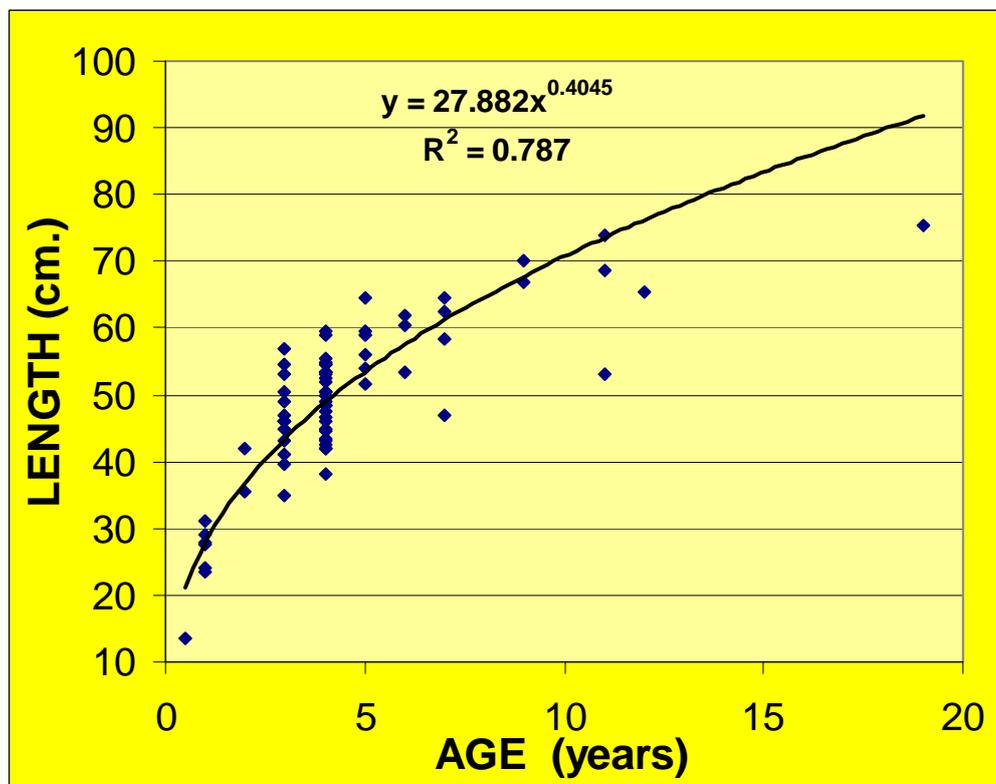


Figure 4. Age-length relationship of *M. rubra* (N=72).

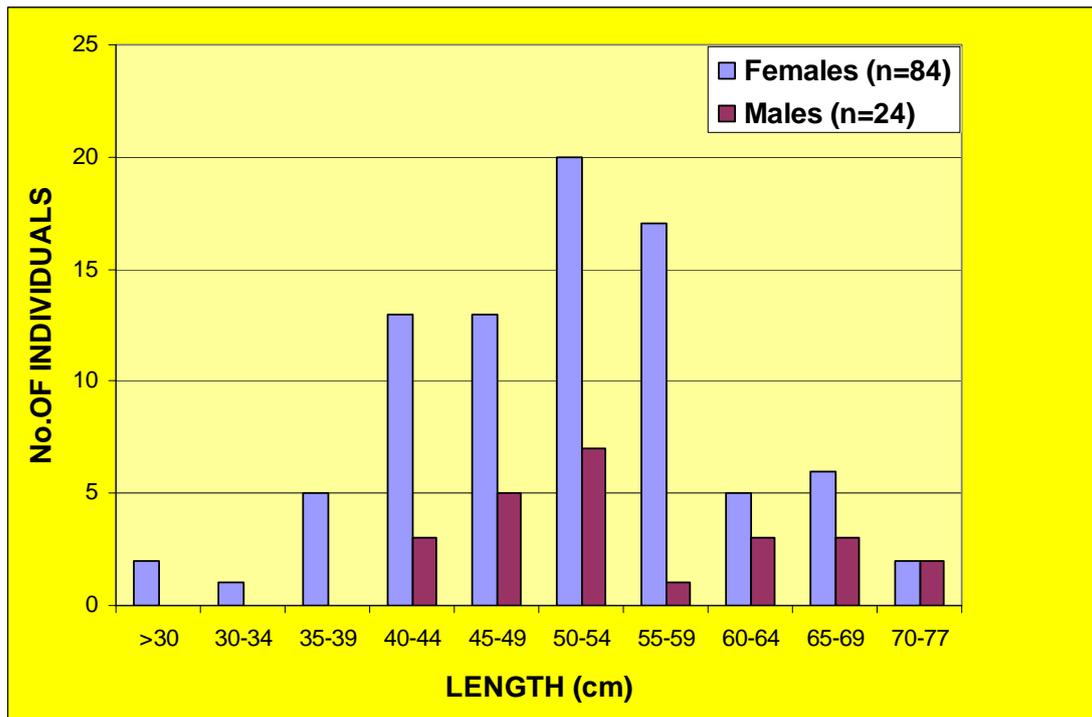


Figure 5. Length-sex relationship of *M. rubra*

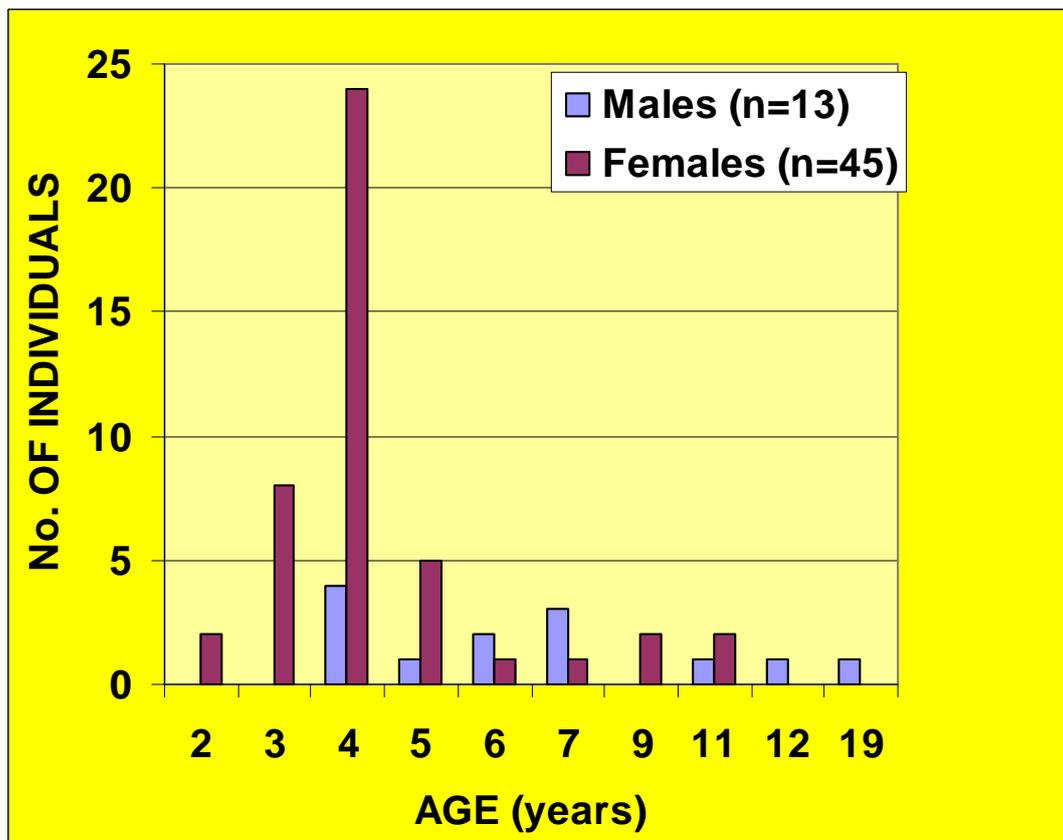


Figure 6. Age-sex relationship.

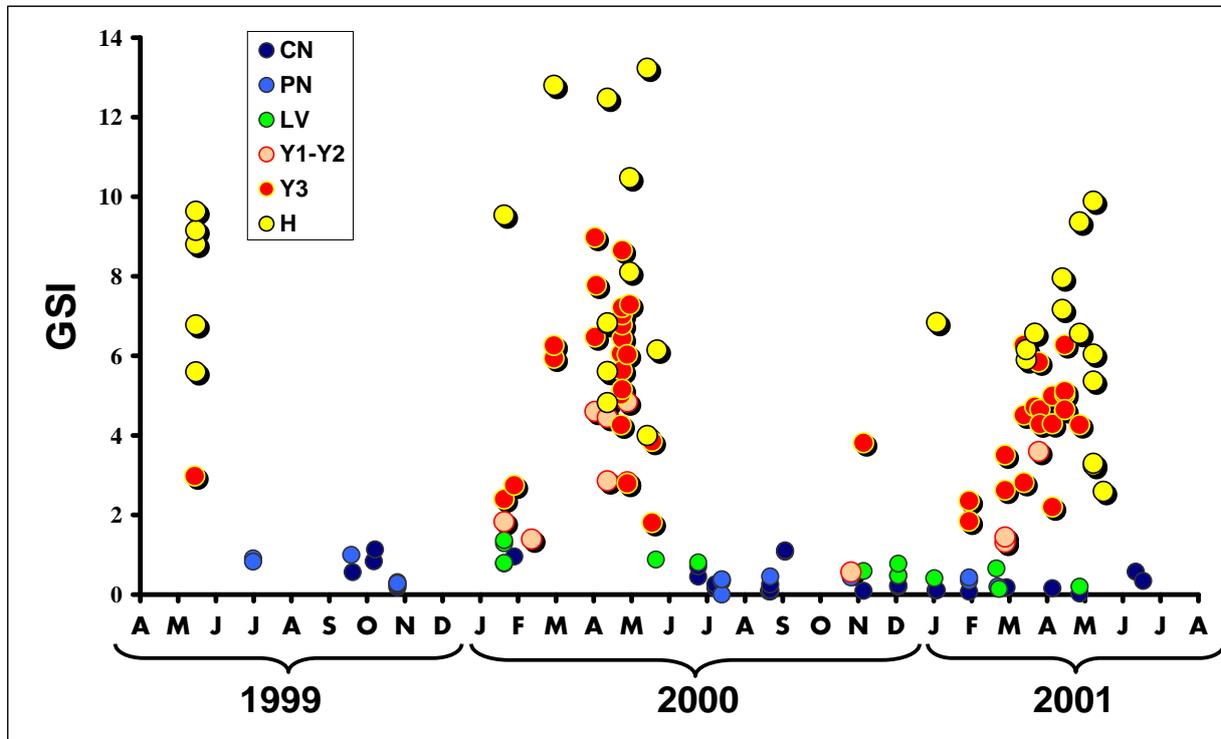


Figure 7. Gonado-Somatic Index and oocytes maturity stage of *M. rubra* throughout the study period. The mark represents the highest oocyte stage found in the ovary. CN=chromatin-nucleolus, PN=peri-nucleolus, LV=lipid vesicle, Y-1/2/3=yolk, H=hydrated. Classification of the oocytes following Marino et al. (2001).

The results are presented in Figure 7 (n=81 females). As evident from this figure, the reproduction period begins in February-March and lasts till the end of May. The scarcity of results during 1999 was due to bad sea conditions. It is also evident from the figure that all females with GSI>10% possess mature oocytes in their ovaries. However, such oocytes are also found in fish with GSI of 4%. The latter ovaries were probably sampled after spawning.

Spawning aggregation

M. rubra aggregated in the nature reserve of Rosh Hanikra for periods of a few days to two weeks every month from the middle of

January until the beginning of June. The aggregation took place in an area of about 2000 m². The number of *M. rubra* counted in this area during a non-aggregation period varied from 0 to 50, whereas during the aggregation period ranged it from 40 to a maximum of ca. 500 (Figure 8). Most of these aggregations were seen in the first half of the lunar month (between the new and the full moon). The rocky substrate in this site combines rocky cliffs and very complex caves alongside flat rocky or sandy bottom. At the same site during the last month of the aggregation period (early May- early July) two other grouper species (*Epinephelus marginatus* & *E. costae*) were also seen



Figure 8. Reproductive aggregation of *M. rubra*.



Figure 9. Color variations during *M. rubra* spawning aggregation.

aggregating, probably for spawning, but their numbers did not exceed 100 individuals.

Eleven additional aggregation sites were recognized along the Israeli coast in unprotected areas. The aggregations were less regular than in the nature reserve. The number of fish in these aggregations was occasionally similar to that of Rosh Hanikra, but in most cases it was much lower.

Personal communication from spear fishermen in these sites revealed the sites to be traditional (>15, 40 years) reproduction aggregation sites.

During winter and spring the aggregations were found at depths of 10-15m. Divers and fishermen reported that the fish had been observed aggregating at depths of 30-40m until mid July.

Color variations

During the aggregation period at least three different color patterns were observed: dark pattern, bright pattern and spotted pattern (Fig. 9).

Fecundity

The numbers of oocytes in ten females of different body weights were counted. The results are shown in Fig. 10. As evident from this figure the relationship between fecundity and body weight is almost linear. The number of oocytes is $568,745$ ($SD \pm 103,465$) oocytes X female weight (kg).

Diet

The stomach contents of 205 mottled groupers were examined. 145 stomachs were found empty. The contents of the remaining 60 stomachs (ca 30%) are presented in Table II. Fish composed 98% of the stomach contents expressed as both number of items and biomass. Rabbit fishes (*Siganus spp.*) dominated the diet of the mottled groupers, comprising ca. 2/3 of it.

Discussion

Fish size

The maximum size reported for *M. rubra* to date was 75 cm TL (Heemstra & Randal 1993, Siau & Boauin 1994), but here we examined specimens of 83.5 cm TL and also found evidence for the presence of specimens of 95 cm TL in Israeli waters (based on analysis of photographs). This finding of specimens longer than in other parts of the distribution region of the mottled grouper does not agree with the "Levantine nanism theory", which expects smaller individuals along the Israeli coast than their conspecifics in the western Mediterranean (Por, 1989, Spanier personal communication). Another finding that rejects this theory for the mottled grouper results from a comparison of the lengths of fish in particular age groups in Tunisia (data modified from Siau & Boauin, 1994) and Israel (Figure 11). As clearly evident from this comparison, the Israeli fish are longer for most of the age groups. The contradiction between the "Levantine nanism theory" and our own findings can be explained either by limiting the nanism theory to species of temperate-cold origin (*M. rubra* is a warm water species that occurs in coastal waters from North Africa to Senegal) or to the unique feeding opportunities opened up for the mottled grouper along the Israeli coast following the invasion and population explosion of rabbit fishes from the Red Sea.

Sexual maturity and sex reversal

M. rubra is a protogonic hermaphrodite. As was found for most groupers (Heemstra & Randal, 1993), the males of the eastern Mediterranean mottled grouper are fewer, older and longer than the females. The fish reaches sexual maturity, in Israeli waters, at the age of 2+ and at a length of 35-36 cm TL. Similar data were reported for the Tunisian population (Siau & Boauin 1994), where all females longer than 32 cm SL (corresponding to 38 cm TL) were found to

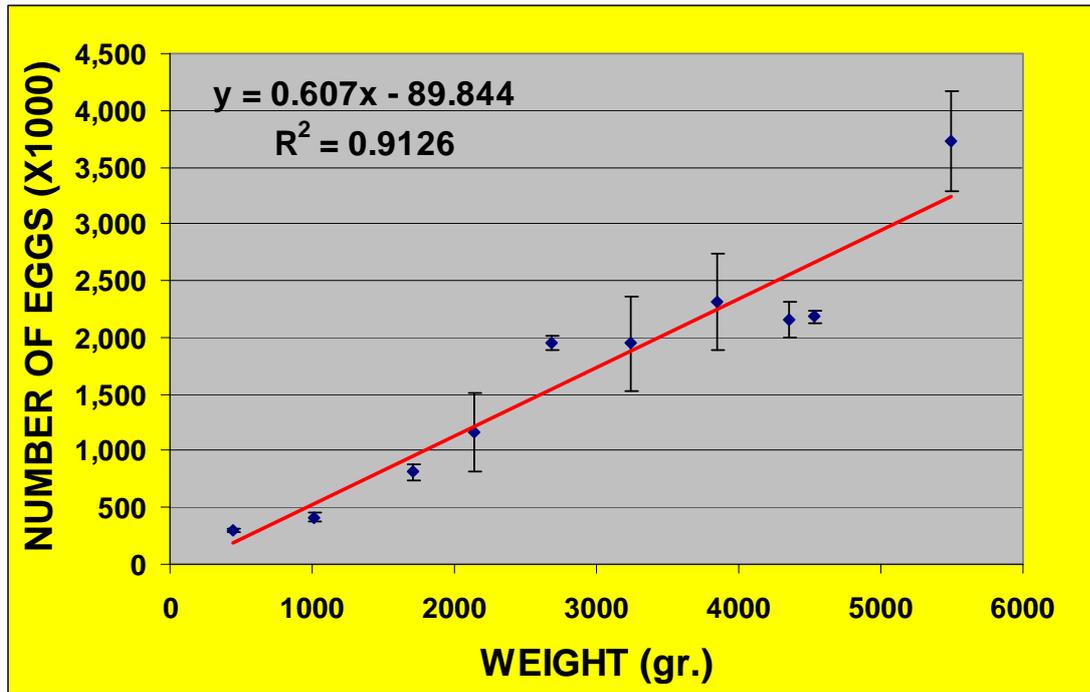


Figure 10. Relationship between body weight and number of oocytes .

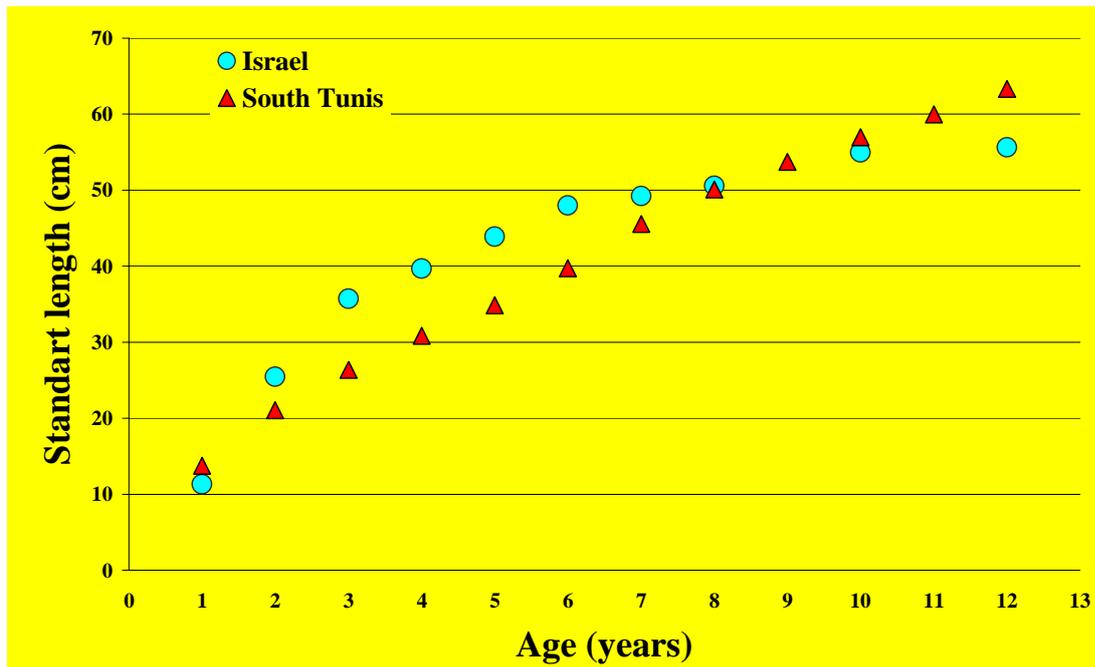


Figure 11. A comparison between lengths of *M. rubra* at given ages off the Tunisian and Israeli populations.

be sexually mature. However, we have no evidence that the smallest mature females actually spawn, and we thus have to consider the possibility that, as in the case of *E. marginatus* (Zabala et al., 1997a), small females do not spawn.

Spawning season

A few specimens of *M. rubra* showed high GSI in early winter; however, the peak breeding season lasts from February to early June. Siau & Boauin (1994) reported that spawning of *M. rubra* in Sfax (southern Tunisia) takes place only at the end of the spring. We assume that the spawning season in the Israeli population begins earlier due to the higher water temperature during winter and spring along the eastern Mediterranean.

Since the aggregation of breeding mottled groupers, in Israel, lasts for one-two weeks each month, for at least 4 months, we assume that this species has several spawning turns each breeding season. We also assume, on the basis of examination of the ovaries, that most females spawn more than once during the breeding season.

Spawning aggregation

Breeding aggregations of various species of groupers at traditional spawning sites are well documented (Bullock & Murphy, 1994; Colin et al., 1987; Gilmore & Jones, 1992; Hermelin et al., 1992; Sadovy et al., 1994a; Sadovy et al., 1994b; Shapiro et al., 1993b; Shapiro et al., 1993a; Tucker et al., 1993). Coleman et al. (1996) suggest that all grouper species longer than 40 cm TL aggregate for spawning. Although *M. rubra* exceeds 85 cm, there are, so far, no reports of spawning aggregation of this species. During the course of this study twelve sites of aggregation were identified along the Israeli coast. Some of these sites are known to have been active for at least 16 years (observations and fishermen's reports). In some of those sites we estimated the mottled grouper density to be as high as 500 in an area of ca. 200m². Such high densities of groupers were recorded for *E. Striatus* in the

tropics (Colin et al., 1987, Heemstra & Randal 1993), but not for the Mediterranean groupers. In the Mediterranean, *E. marginatus* have been reported to form much smaller spawning gatherings (<100 individuals) during the breeding season (Zabala et al., 1997b, Marino et al., 2001).

During the aggregation period the fish were observed swimming a few meters above the bottom. A similar behavior pattern was observed in *E. striatus* from the western Atlantic (Colin 1992).

Changes in color patterns were well documented in many serranid species. Such color changes during aggregation are part of their sexual communication behavior (Colin, 1992; Gilmore & Jones, 1992; Zabala et al., 1997b). The mottled grouper shows at least three color patterns during the breeding season; however, in spite of the numerous hours of observations, we are not yet able to relate the changes in color patterns to any specific behavioral pattern.

Fecundity

The relationship between number of oocytes and body weight was found to be linear. The fecundity of the females is at least ca. 580,000 oocytes *weight (kg) per year.

Food-dependent distribution?

As evident from the present results, the diet of *M. rubra* is based almost exclusively on fish. The dominant prey is the rabbit-fish – *Siganus spp.* (68% of the biomass of the stomach content). This finding is interesting for two reasons: first, the high proportion of a single prey item in a grouper diet. Other *Mycteroperca* species feed on a much greater variety of food, although fish is their dominant prey (Bullock, 1994); and second, the fact that the rabbit-fish, a poisonous species, is a main food component for a predator species. The rabbit-fish is an invader from the Red Sea (Golani, 1998; Por, 1989) that has become common along the Israeli coast and comprises more than 30% of the fish biomass in the rocky habitats

(Goren & Galil, 2001). We suggest that the success of the mottled grouper in establishing a large population in the eastern Mediterranean (about 50% of the total grouper biomass in shallow rocky habitats) is mainly due to an anthropogenic effect: the opening of the Suez Canal that enabled the invasion of the rabbit fishes *Siganus rivulatus* and *S. luridus* into the eastern Mediterranean. This invasion created an unlimited food resource for the mottled grouper that consequently has become the most common grouper in the region, whereas in other parts of the Mediterranean this grouper is much less common or completely absent.

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