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Reproductive biology of the Golden grey mullet *Liza aurata* (Risso, 1810), in the Gulf of Gabes (central Mediterranean, Tunisia)

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Abstract

In this study, some biological characteristics of the Golden grey mullet from the Gulf of Gabes (central Mediterranean, Tunisia) were examined; in particular, the gonado somatic index (GSI), hepato somatic index (HSI), condition factor (K), length at first sexual maturity (TL50) and fecundity (volumetric method) were calculated. The gonadosomatic index (GSI) indicated that the spawning season of the Golden grey mullet extends from October to December. The monthly variation of the hepato-somatic index (HSI) indicates that L. aurata saves lipid reserves in the liver. The length at first sexual maturity (TL50) was determined to be 23.73, 23.84 and 23.79 cm TL for female, male and combined sexes, respectively. In this study, the sex-ratio was unbalanced, with females dominating among large sized individuals (TL > 24.0 cm). Absolute fecundity, with a mean value of 286564, varied from a minimum of 210400 eggs for age 4+ to a maximum of 533600 for age 7+.

Keywords: *Liza aurata*, Golden grey mullet, reproduction, Gulf of Gabes.

Introduction

Reproduction is one way throughout fish can generally ensure the sustainability of their communities. Hence, various reproductive strategies including migration and fast gonad maturation are commonly used to maximize the breeding opportunities.

The Golden grey mullet, *L. aurata* (Risso, 1810), named Ommila in the Gulf of Gabes, is a semi pelagic gonochoristic species belonging to the Mugilidae family, contributes largely to the fisheries in estuaries, backwaters and inshore areas of the Mediterranean Sea because of its abundance and high potential adaptability to various biotopes. The golden grey mullet is widely distributed along the Atlantic coast from Morocco to the Bay of Biscay (Trewavas, 1973) and along both the European and African coasts, as well as in the Mediterranean and Black sea where it plays a crucial economic role in supporting artisanal fisheries (Mc Dowall, 1988; Blaber, 1997). The Average total catch in 2010 in Tunisia was estimated at 1406.44 t (Anonymous, 2011). Along the south eastern Tunisian coast (Gulf of Gabes), *L. aurata* is targeted by gill nets and purse seines; the Tunisian fisheries restriction for the Golden grey mullet indicates a legal size of capture of about 25 cm (TL).

In the central and eastern Mediterranean, several studies on its biology and fisheries have dealt mainly with ecology (Katavic, 1980; Fazli *et al.*, 2008), age and growth (Arruda *et al.*, 1991; Koutrakis & Sinis, 1994; Fehri-Bedoui & Gharbi, 2005; Abdallah *et al.*, 2012), breeding season (Arne, 1938; Gondolfi & Orsini, 1968; Hotos *et al.*, 2000; Fehri-Bedoui *et al.*, 2002), morphological characters (Minos *et al.*, 1994) and seasonal occurrence of fry (Katselis *et al.*, 1994). The aim of this work was to study certain biological parameters of *L. aurata* in the Gulf of Gabes in order to improve current knowledge of the species for the purpose of rational use of resources and in order to compare these results with those of previous studies.

Material and Methods

Study area

Catches were made in the Gulf of Gabes, south-eastern part of Tunisia (Fig. 1). The Gulf of Gabes, due to its topography and the presence of vast fields of phanerogams, represents an exceptional nursery for the reproduction and development of numerous marine species (Bradai, 2000; Ben Salem *et al.*, 2002), and stretches from Cape Kapoudia to the Tunisian – Libyan borders for about 750 km.

Sampling and sample elaboration procedure

Between October 2006 and September 2008, a total of 876 samples were randomly taken from commercial

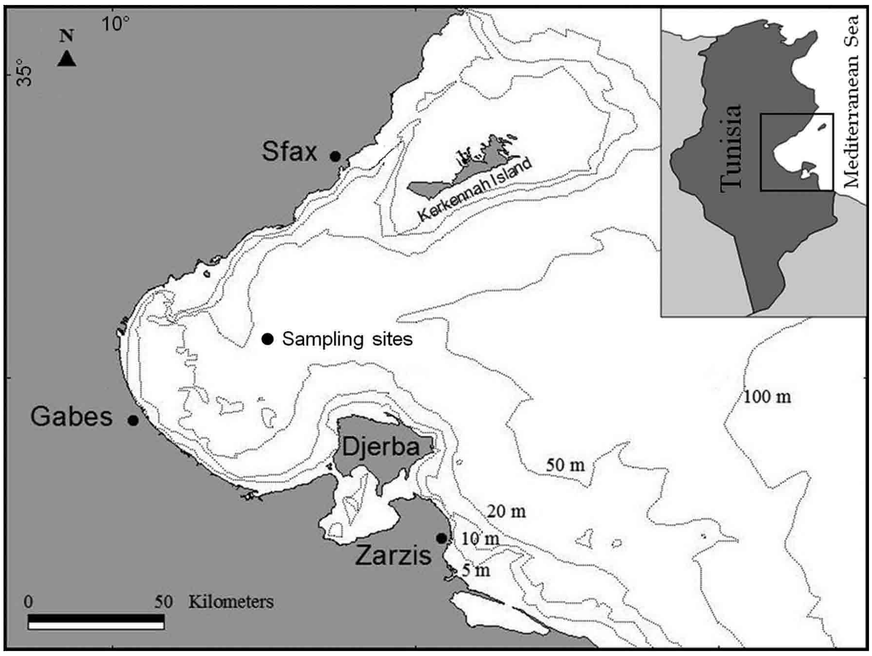

Fig. 1: Geographic location of the study area (Gulf of Gabes).

purse seine nets (stretched mesh of 24 mm) and gill nets (stretched mesh of 60 mm) catches. At the laboratory, total length (TL) and standard length (SL) were measured to the nearest 1 mm. The total weight and eviscerated body weight were measured to the nearest 0.1 g. The gonads and liver were measured to the nearest 0.01 g.

The gonadosomatic index (GSI) was calculated monthly according to the formula: GSI % = gonad weight x 100 / eviscerated body weight.

Accumulation and depletion of body reserves was studied through the analysis of monthly hepatosomatic index (HSI) changes and those of the condition factor (K), since liver and muscles are the main organs responsible for lipid reserve storage. These indexes were calculated as follows:

(HSI, where HSI = 100 x Liver weight / Eviscerated body weight); (K, where K =100 x Eviscerated body weight / $(TL)^3$). The degree of maturity of the gonads was determined both in females and males according to the six-stage maturity scale described by Gaamour (1999).

The length at first sexual maturity (TL_{50}), i.e. the size at which 50% of the individuals are mature, were estimated from the logistic curve parameters (King, 1995): P = 1/ [1+exp [-b (L-Lm50)]] where, P is the proportion of mature individuals at a given length (TL), b is the slope of the maturity curve and Lm50 is the total length at which 50% of the fish are mature. Data were calculated using the 'FSAS' software package (Saul *et al.*, 1987).

The sex-ratio [SR=F*100/ F+M] was determined monthly and the results were statistically tested (χ^2 test of homogeneity).

The fecundity analysis was performed on 68 ripe females (stage IV and V). For the fecundity estimation, the volumetric method (Gaamour, 1999) was employed. The ovaries were placed in a beaker with a known volume of water and mixed with a magnetic stirrer; subsequently, five sub-samples were obtained using a 2 ml stamped pipette and the variance was analysed in order to test homogeneity. Fecundity relative to length and weight was calculated.

Results

A total of 876 individuals of *L. aurata* were examined, 344 were females (15.9 cm to 30.4 cm TL) and 236 were males (16 cm to 28.9 cm TL). The remaining 296 individuals (8 cm to 14.3 cm TL) (33%) could not be sexually determined. The external identification of sex was impossible since the species does not exhibit any sexual dimorphism.

Sexual cycle and spawning period

Following the seasonal evolution of the mean GSI, three stages can be identified for the female *L. aurata* reproductive cycle (Fig. 2.): A quiescence phase (January to September) marked by very low GSI; a phase of fast maturation during October (5.19); and a spawning phase as perceived by a clear GSI fall (3.50) in November that extends until December (0.92). Although the GSI values of males are lower than those of females the same sexual cycle stages are noticed: the phase of gamete maturation is located in late September and October (2.44). The spawning period takes place in November to December (0.07). The resting phase extends from January (0.15) to September (Fig. 3).

Hepato Somatic Index (HIS)

The HSI variation among females was similar to those of the GSI. It reached a maximum value in Septem-

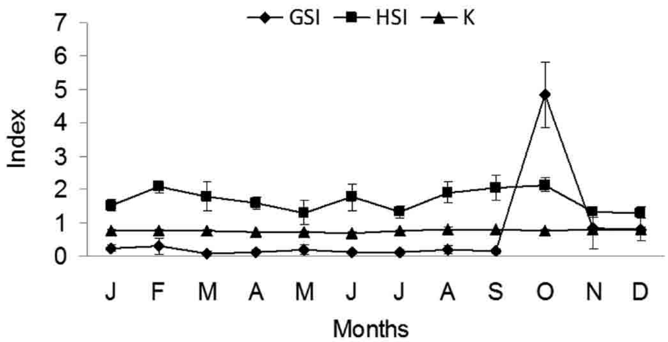

Fig. 2: Monthly variation of the Gonadosomatic Index (GSI); the Hepatosomatic Index (HSI); and the condition factor (K) for females of *Liza aurata* in the Gulf of Gabes (means ± confidence limit).

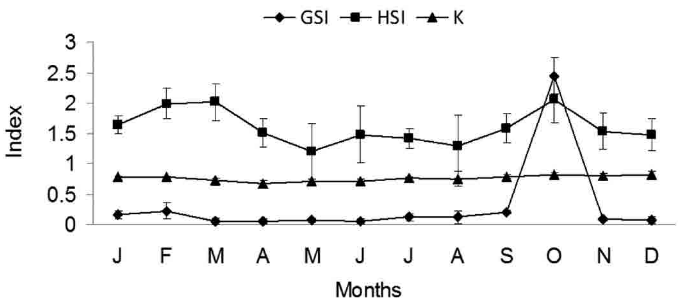

Fig. 3: Monthly variation of the Gonadosomatic Index (GSI); the Hepatosomatic Index (HSI); and the condition factor (K) for males of *Liza aurata* in the Gulf of Gabes (means ± confidence limit).

Table 1. Parameters of the sexual maturity of *Liza aurata* in the Gulf of Gabes. TL_{50}, total length at first sexual maturity; L_{25}, total length at 25% sexual maturity; L_{75}, total length at 75% sexual maturity; $\chi 2$, $\chi 2$-tests; and the P test of significance for $P < 0.05$, R^2: Regression coefficient.

Parameters	*Males*	*Females*	*Combined sex*
b	0.84	0.95	0.89
R^2	0.98	0.99	0.99
L_{50} (cm)	23.84	23.73	23.79
L_{25} (cm)	22.54	22.57	22.56
L_{75} (cm)	25.13	24.88	25.01
Calculated χ^2	6.53	2.06	4.75
Theoretical χ^2	26.29	26.29	26.29
Test (P)	P>0.05	P>0.05	P>0.05

ber (2.03), which corresponds to the beginning of gonad maturation while showing slight variation during other months. Among males, the HSI showed many oscillations with the highest value recorded in October (2.05) (Fig. 3).

Condition Factor (K)

Figures 2 and 3 show that the monthly condition factor K values do not present considerable variations, for both females and males.

Size at first sexual maturity

The size at first sexual maturity for male and female *L. aurata* was determined in 554 individuals. No male individuals were mature at size (TL) < 20 cm (Fig. 4); however, among females, the first mature individuals were observed at total length size of 21 cm (Fig 5). For the population, 50% of the males and females attained first maturity at 23.84 cm TL and 23.73 cm TL respectively, indicating that both sexes are generally mature at the same age approximately. The χ^2 - test showed that for both sexes χ^2 remained much higher than the calculated values (calculated χ^2 < theoretical χ^2). It can be deduced that the logistic function is well adjusted to the observed data. The different values of the logistic function, adjusted to the relative data of the first sexual maturity of male and female *L. aurata*, are presented in Table 1.

Sex ratio

Out of the 580 specimens whose sex was identified, 344 were females (F) and 236 were males (M), giving an

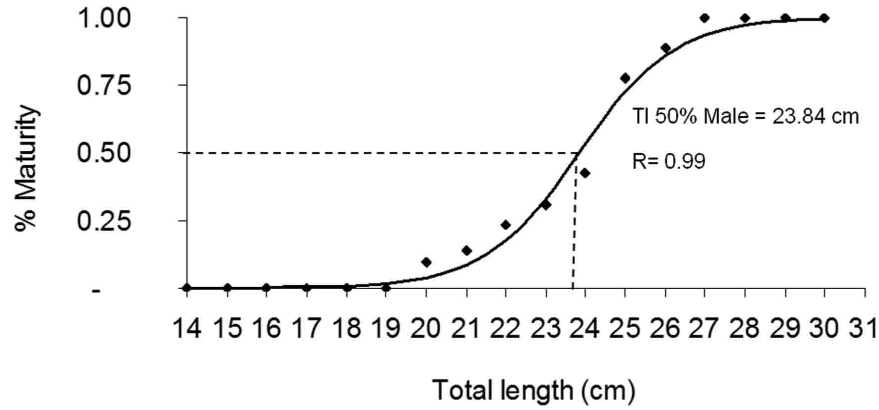

Fig. 4: Relationship between proportion of maturity and Total length for males of *Liza aurata* in the Gulf of Gabes.

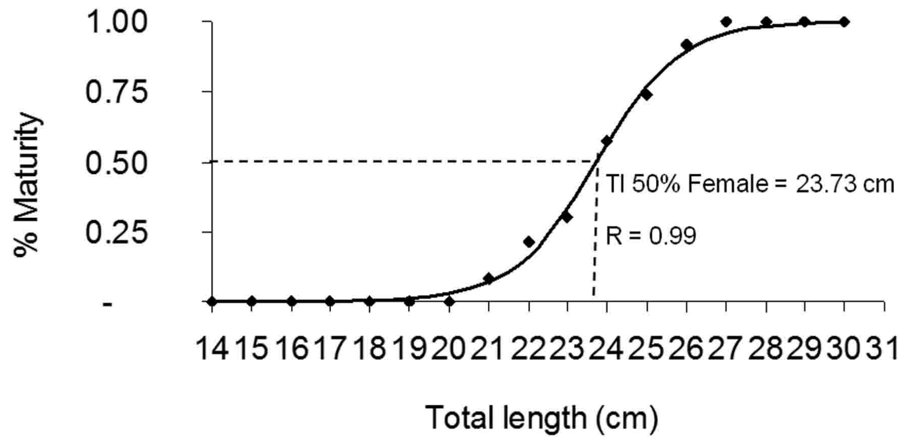

Fig. 5: Relationship between proportion of maturity and Total length for females of *Liza aurata* in the Gulf of Gabes.

overall sex-ratio of 59.31 % (♀: ♂ = 1.45:1) for females, which significantly deviated from the hypothetical distribution of 1:1 (χ^2 calculated = 25.20 > χ^2 theoretical = 3.84; $p < 0.05$). Although equality between sexes was recorded most of the year, females were found to outnumber males in August, October and November (Fig. 6).

Regarding the changes in sex distribution in relation to size, it was found that the sex-ratio was statistically balanced (equal to 50%), from 16 to 24 cm TL ($P = 9.38 > 0.05$). The females were predominant at lengths larger than 24 cm TL, except at sizes 27 and 29 cm where parietal distribution returns (Fig. 7).

Fecundity

Absolute fecundity was determined on 68 ripe females (age 4 to 7+) caught in September / October. A maximum value of 533,600 eggs was recorded in 7+ year old fish weighing 242.7 g and a minimum value of 210,400 eggs for a 4 year-old fish weighing 68 g. The mean value was 286,564 ± 17,707 (SD= 74502). The absolute fecundity to fish length (33902 TL- 48717; R^2 = 0.81) and weight (2329 EW + 92777; R^2 = 0.82) were positively correlated.

Fecundity relative to total weight fluctuated from 2100 to 4254 eggs/g, with a mean value of 2952 ± 125.96 (SD) and relative to total length from 9527 to 18,734 eggs/cm with a mean value of 12,444 ± 519.45 (SD).

Discussion

The reproductive biology of *L. aurata* has been investigated for the first time in a specific area of the Gulf of Gabes (south-eastern Tunisian coast). The reproductive cycles of both males and females are synchronized. The gonad pre-maturation phase is practically inexistent since maturation, which occurs in October, immediately follows the long period of quiescence (January to September), while spawning occurs in November and December. In the Mediterranean, the breeding period of the Golden grey mullet is very brief and occurs almost during the same period at different localities. Gondolfi & Orsini (1968) and Ghittino (1983) reported that breeding occurs from September to November in Italy. The study conducted in western Greece by Hotos *et al.* (2000) indicated an earlier and much longer period, namely, from August to November. Cambrony (1983) who studied *L. aurata* in the Languedoc area found a reproductive cycle that extends from August to October (Table. 2). In

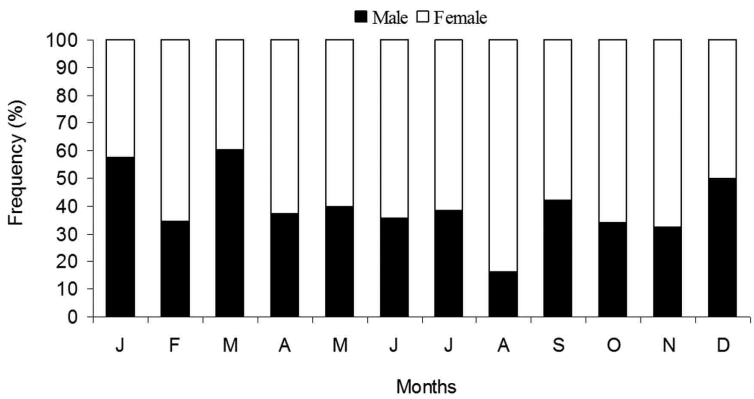

Fig. 6: Monthly evolution of the sex proportions (%) of *Liza aurata* in the Gulf of Gabes.

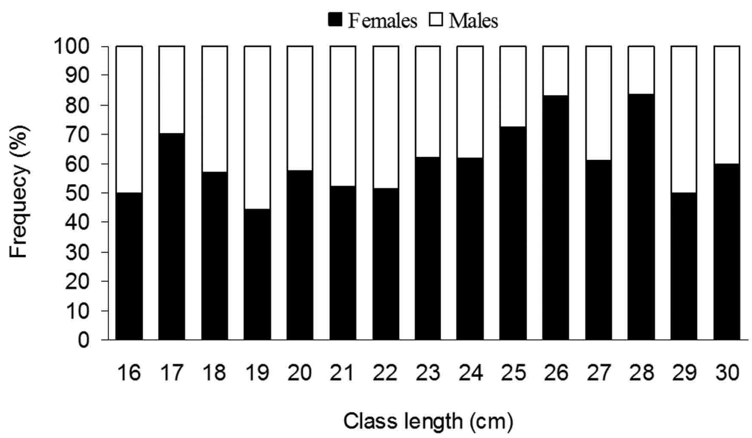

Fig. 7: Sex-ratio evolution by size class for *Liza aurata* in the Gulf of Gabes.

Table 2. Spawning period of *Liza aurata* from different Mediterranean localities.

Authors	*Area*	*Spawning period*
Hotos et *al.* (2000)	West Greece	August to November
Fehri- Bedoui et *al.* (2002)	Tunisian coasts	October to November
Ghondolfi & Orsini (1970)	Laguna de Venezia (Italy)	September to November
Cambrony (1983)	Languedoc	August to October
Present Work	Gulf of Gabes (Tunisia)	October to December

Tunisian waters, Fehri-Bedoui *et al.* (2002) reported a very brief breeding season in October- November. As indicated above by the authors, the synchronous breeding season is probably due to the similarity of the environmental features of water (temperature and salinity) in late summer in the Mediterranean Sea, as these conditions are crucial for enhancing gonad maturation in grey mullet.

GSI values among ripe females are higher than those of males; in Tunisian waters, the GSI values of females appear to be around 5, while lower values (about 2) have been recorded for males (Fehri- Bedoui *et al.*, 2002; Abdallah, 2005). The difference between male and female GSI values suggests that energy invested by males for gamete production is probably less than that invested by females; this could be due to physiological and hormone effects on the gonadal development of fish. The monthly progress of HSI showed that both sexes of the golden grey mullet, with respect to different levels of reproductive investment, use the liver for storage and mobilization of reserves in order to nurture their gametes and ensure spawning when needed. Storage of fat within the liver during the reproductive period is a strategy adopted by many species (Bailey, 1952; Smith, 1957; Bertin, 1958) belonging to the gadus type (Bougis, 1952).

First sexual maturity is reached at size >26 cm (TL) for all *Liza aurata* specimens. The smallest reproducing individuals were observed at 19.6 cm (TL) for males and 20.8 cm (TL) for females aged 3+. The mean first maturation (L_{50}) of the golden grey mullet occurs at age 5+ (Abdallah *et al.*, 2012), 23.84 cm and 23.73 cm

(TL) for males and females respectively. Thong (1969) reported an age of 3+ for the golden grey mullet inhabiting the gulf of Gascoigne. The study conducted by Ezzat (1965) indicated that the species was mature at size 27 (age 3+) and 34 cm (age 4+) respectively for males and females in the gulf of Marseille. Fehri-Bedoui & Gharbi (2005) determined that specimens of 21.95 cm and 21.41 cm respectively for females and males, corresponding to age 3+, are sexually mature in Tunisian waters. Hotos *et al.* (2000) assert that first maturation of the Golden grey mullet in the Klisova lagoon (W. Greece) occurs at age 1+ for both sexes. Ghaninejad *et al.* (2010) note that the golden grey mullet of the Caspian Sea is mature at 28.4 cm (FL), while Fazli *et al.* (2008) estimated maturity at 26 cm (FL) in Iranian coastal waters; a significantly close size (26.6 cm) was reported by Daryanabard *et al.* (2009) in the same locality. Saad & Hamoud (2001) estimated the maturity length at 50% of *Liza aurata* inhabiting Syrian waters (Eastern Mediterranean) to be 34 cm (Tl).

Considering the above, high variability in first maturation is observed. Generally, the lowest ages are recorded in the Mediterranean. The differences are attributed mainly to the variability of environmental conditions in different areas, with low temperature and photoperiod probably being the main factors (Nash & Koningsberger, 1981; Buslé, 1982) influencing first maturity via hormones, and even causing inter-annual variations in the same area (Thomson, 1966).

Ezzat (1965) asserts that first maturation of *Liza ramada*, which is morphologically the closest species to the golden grey mullet, occurs at sizes of 33 and 37 cm respectively for males and females in the gulf of Marseille

The legal size of capture for the Golden grey mullet *Liza aurata* (25 cm TL) indicated by current Tunisian legislation seems to be well adapted to the size of first sexual maturity estimated in this study; given that 75 % of individuals are sexually mature at a size of 25 cm (TL).

The analysis of the sex proportion showed significant differences between the proportions of males and females, according to month and size. Overall, females outnumbered males (1: 1.45), which is a significant departure from the hypothetical 1:1. This result is in agreement with the findings of several authors (Ghadirnejad, 1996; Ghaninejad *et al.,* 2010). Considering size class distribution, it is notable that the sex-ratio is equitable for the smallest individuals and in favour of females as of the 25 cm TL class size. Over months, the sex ratio was statistically either parietal or in favour of females. The phenomenon of female predominance in the old age group has been reported for mullet species (Quignard & Farrugio, 1981; Ghadirnejad, 1996, Ghaninejad *et al.,* 2010) as well as for other species. This is likely due either to selective fishing in relation to the morphological differences and behavioural procedure among sexes (Wenner, 1972), as ripe females are heavier and consequently more vulnerable or to a different longevity that may modify sampling in relation to the real population (Keverkidis *et al.*, 1990).

In this study, the mean absolute fecundity of the golden grey mullet was 286,564. In previous research conducted by Ghadirnejad (1996), the absolute fecundity was found to be 888,668 eggs. Askerov *et al.* (2003) noted that the absolute fecundity of 25-30 cm *Liza aurata* was an average of 500-600 thousands eggs, which increases to 2-3 million eggs among those sized 45-50 cm in length. For the same species, Ghaninejad *et al.* (2010) reported a fecundity range of 200,112 to 228,2862 eggs with a mean of 700,881, while Hotos *et al.* (2000) reported a fecundity range of 80,000 to 1,410,000 eggs, with a mean of 700,881 and Pillay (1972) stated that absolute fecundity ranges from 157,000 to 926,000 eggs. Information on this topic for other localities in the Mediterranean Sea is lacking.

The results of this study might help rational exploitation of the resource by providing the scientific support required to identify the current stock state.

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