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Age, growth and length-weight relationship of the white skate, *Rostroraja alba* (Linnaeus, 1758) (Chondrichthyans: Rajidae), from the Gulf of Gabes (Tunisia, Central Mediterranean)

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PEER REVIEW

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Comments

This manuscript provides basic information about some biological parameters of *R. alba* in the Gulf of Gabes. The stated purposes for this study were to provide an effective tool for fishery biologists, managers and conservationists to initiate management strategies and regulations for the sustainable conservation of the remaining stocks of this species in Southern Tunisian waters and elsewhere in the region.

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ABSTRACT

Objective: To investigate the length distribution, sex ratio, length-weight relationship, age and growth of *Rostroraja alba* in the Gulf of Gabes.

Methods: This study estimated age and growth of the white skate, *Rostroraja alba* by counting vertebral band pairs from 112 specimens taken by commercial fisheries during 2006-2009 from the Gulf of Gabes (Southern Tunisia, Central Mediterranean Sea).

Results: This is the first and only known information in regards to the age and growth of this species in Tunisia. Vertebra diameter was strongly correlated with total length and age, which were expressed by linear or cubic regression equations. The oldest female in this study was 35 years and 160 cm, whereas the oldest male was 32 years and 150 cm. The von Bertalanffy growth parameters were TL_∞=(202.26±3.40) cm, K=(0.040±0.038)/year and t_0=(1.84±0.01) 10^{-1}/year for females and TL_∞=(198.60±3.61) cm, K=(0.060±0.076)/year and t_0=(1.28±0.04)/year for males.

Conclusions: This study would be an effective tool for fishery biologists, managers and conservationists to initiate management strategies and regulations for the sustainable conservation of the remaining stocks of this species in the Gulf of Gabes (Southern Tunisia) ecosystem.

KEYWORDS

Age and growth, Mediterranean Sea, Gulf of Gabes, Vertebra, *Rostroraja alba*

1. Introduction

The white skate is distributed in the Eastern Atlantic from the British Isles southward, also along the coast of Africa and in most of the Mediterranean (to Tunisia and Turkey)[1-3].

In spite of the increasing fishing pressure, there is a paucity of information on white skate life history resulting in an assessment of 'critically endangered' on IUCN Red List assessments for Chondrichthyans in the Mediterranean Sea[4].

There is very little information on the reproductive parameters of *Rostroraja alba* (*R. alba*), but no studies on the age and growth of these species in the Mediterranean.

This study provides the first estimate of age and growth parameters of the white skate in the Central Mediterranean (Tunisian south coast), based on vertebrae from wild-caught specimens collected in the Gulf of Gabes. The results derived from this study provide very important and useful information for conservation and management of this

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species.

2. Materials and methods

2.1. Sample collection

Specimens were collected by a commercial fisherman using trawl 'Said' using a 22 mm stretched mesh size cod-end and operating over 30 m depth (Figure 1), between January 2006 and December 2009. In the laboratory, a total of 450 specimens were measered randomly. The total length (TL in cm) was measured as a straight line from the tip of the rostrum to the end of the tail. The total wet weight (in grams) to the nearest 10 g was also recorded.

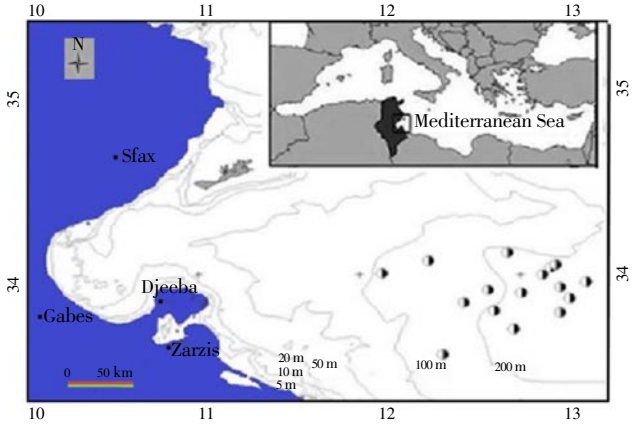

Figure 1. Sampling areas of *R. alba* in the Gulf of Gabes (Southern Tunisia).

2.2. Preparation of vertebral samples

A block of 10 vertebral centres were taken from above the abdominal cavity of 112 *R. alba*, labeled, and stored frozen[5]. Soft tissue was removed from the frozen vertebral segments using a scalpel. The individual vertebrae were then cut apart from each other and soaked in warm distilled water. Hypochlorite (5%) was used to remove the last remaining bits of connective tissue from the vertebrae. However, hypochlorite can decalcify cartilage when overused, so soak times were kept to nearly 10 min. The vertebrae were then air-dried for no less than 48 h. One vertebra from each specimen was cut through the focus with a double bladed low-speed saw to create sagittal thin section, which was mounted on glass slides and dry sandpapered to produce a thin section of 0.6 mm.

2.3. Counts of annuli

Vertebral sections were examined under a compound and were digitally photographed with a camera attached to an Olympus S2X9 stereomicroscope with a reflected light at ×20 magnification. Growth bands were counted using the image analysis software TNPC 4.1[6]. Liquid clarifier (EDTA) was applied to the section surfaces to enhance the banding pattern. One growth band was defined as an opaque and translucent band pair that traversed the intermedialia and clearly extended into the corpus calcareum[7].

The index of the average percentage error (IAPE)[8], the coefficient of variation (CV)[9], and the age-bias plot[10], were then used to compare reproducibility of the age determination between readings, as follows:

$$IAPE=\frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{R}\sum_{i+1}^{R}\frac{|Xij-Xj|}{Xj}\right)\times 100$$

Where N is the number of animals aged, R is the number of readings, Xij is the count from the jth animal at the ith reading and Xj is the mean age of the jth animal from i readings.

$$CV=100\ \%\times\frac{\sqrt{\sum_{i=1}^{R}(Xij-Xj)/(R-1)}}{Xj}$$

Where CV is the age precision estimate for the jth fish; Xij is the age determination of the jth fish by the ith reader; Xj is the mean age of the jth fish and R is the number of readings.

The von Bertalanffy growth equation[11] was fitted to the data:

$$TL=TL_{\infty}(1-e^{-k(t-t_0)})$$

Where TL = total length at age t, TL_{∞}=theoretical asymptotic length, k=growth rate coefficient, and t_0=the theoretical age at zero length.

The von Bertalanffy growth equation was calculated by using FISHPARM, a computer program for parameter estimation of nonlinear models with algorithm for least-square estimation of nonlinear parameters[12]. An analysis of covariance (ANCOVA) was used to compare the slopes between sexes.

2.4. Marginal increment ratio

The periodicity of band pair formation was investigated using the marginal increment ratio (MIR)[7]. A sub-sample of 112 vertebrae were randomly selected comprising both juvenile and adult specimens collected in every month. The MIR was calculated as the ratio of the distance between the last and penultimate opaque bands as measured with an optical micrometer. The marginal increment ratio calculated by the following equation[13]:

$$MIR=\frac{R-R_n}{R_n-R_{n-1}}$$

Where R is the centrum radius, R_n and R_{n-1} are radius of the ultimate and penultimate annuli, respectively. Kruskal-Wallis One-way analysis of variance on ranks was used to test for differences in marginal increment by month[14].

The growth in mass was also described by the same model.

$$W_t=W_{\infty}\left[1-e^{-k(t-t_0)}\right]^b$$

Where W_t is the total mass at time t, W_{∞} is the maximum theoretical mass of species and b is the power constant of the length mass relationships.

The relation of weight to length was calculated applying

the exponential regression as the following equation:

$W = a \times L^b$

Where W is the total weight (g), L is the total length (cm), b and a are parameters to be estimated. The regression liens between sexes ANCOVA statistic test was used.

The diameter of the first 10 vertebrae from each fish was measured and a mean vertebra diameter [vertebral radius (RV), ±0.05 mm] was estimated for each individual. The relation between RV and TL was determined by regression analysis, using linear and non-linear models for a better comprehension of age and growth characteristics and the use of vertebrae in age estimates.

3. Results

3.1. Length frequency distribution

The sample was composed of 210 females and 240 males. The TL varied from 25 and 150 cm for males and from 30 and 160 cm for females (Table 1). The bulk of samples indicated that a peak occurred at a size of 50-80 cm TL for both sexes (Figure 2). The distribution of length within these ranges was significantly different (Kolmogorov-Smirnov test, D=0.310, n=450, P<0.05). Mean total length was greater for females than for males.

Table 1

The total number of fish, mean (±SD), minimum, maximum, and mode of total length for *R. alba* in the Gulf of Gabes for all fish.

Parameter	Total length (cm)		
	All fishes	Females	Males
N	450	210	240
Min	25	30	25
Max	160	160	150
Mean±SD	64.32± 0.11	76.22±0.08	52.18±0.06
Mode (cm)	55.2	58.1	52.3

N: total number; Min: minimum; Max: maximum.

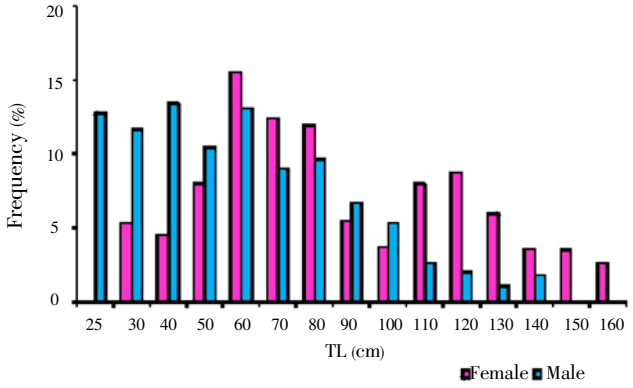

Figure 2. Length-frequency distribution of *R. alba* in the Gulf of Gabes.

3.2. length-weight and vertebra relationships

The length-weight relationships of both sexes separately and all fish are represented in Table 2. There was no statistically significant slope of the length-weight regressions between sexes (ANOVA, P>0.05).

The b value was significantly higher than the theoretical value of 3 for females (t-test, t=2.24, P<0.05), for males (t-test, t=1.25, P<0.05) for females and for all individuals (t-test, t=1,65, P<0.05) which meant a positive allometric growth pattern (P<0.05).

Table 2

Length-weight relationships and regression parameters (a, b, r^2) of *R. alba* in the Gulf of Gabes.

Sex	Equation	N	a	b	r^2	Significance	Allometry
F	$W=0.025\ TL^{3.61}$	210	0.025	3.61	0.96	P>0.05	positive
M	$W=0.017\ TL^{3.53}$	240	0.017	3.35	0.95	P>0.05	positive
F+M	$W=0.021\ TL^{3.57}$	450	0.021	3.57	0.98	P>0.05	positive

Consequently, the different classes of age of *R. alba* were subdivided among age groups. During the first year of life, fish attained over 2% of their maximum observed length. By the end of the 20 and the 35 years, specimens attained approximately 85% and 92% of their maximum length, respectively. Indeed, over 80 % of the aged specimens were between 20 and 30 years.

For the calculation of the fish TL and vertebrae radius relationship, the data from 112 individuals are presented in Table 3 for both sexes and combined sexes. No significant difference was found between the slopes of females and males (ANCOVA, P>0.05) (Table 3). Given a strong linear correlation between the total length and vertebrae radius (Table 3), vertebrae radius measurements were used to back calculate the total length of previous ages.

Table 3

Relationships between total length and vertebrae radius of *R. alba* from the Gulf of Gabes.

Sex	N	a	b	r^2	Size range (cm)
Combined sex	112	229.80	26.10	0.97	25-160
Females	62	235.74	25.91	0.98	35-160
Males	50	221.83	26.23	0.97	25-150

3.3. Marginal increment ratio

The progression of the marginal increment in vertebrae radius is displayed in Figure 3. When the sexes were combined, marginal increments were significantly different between months (Kruskal-Wallis test, (H=15.02, df=6, P=0.04) and was at its minimum during the months of March and April. This indicated that only one translucent zone and its adjacent opaque zone were deposited on the vertebrae radius each calendar year, which represented an annulus.

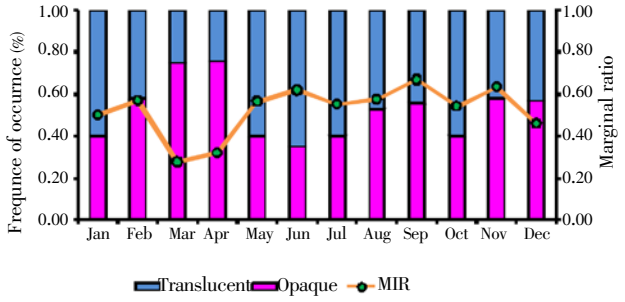

Figure 3. Mean monthly marginal increments of vertebrea for *R. alba* of the Gulf of Gabes.

Error bars=±standard error. MIR: marginal increment ratio.

3.4. Age and growth

The remaining 112 vertebrae, 62 females (25–150 cm TL) and 50 males (30–160 cm TL) were used for age estimation. After separate readings, exact agreement of ring counts were reached on 7% differed by one ring, 4% by two rings and 3% by more than three. The average IAPE of the overall sample was 5.15% and the CV was 3.12. The levels of precision indicated a high level of reproducibility, so these data were used for further analyses.

The oldest males were estimated to be 32 years old (150 cm TL), and the oldest females also 35 years old (160 cm TL). Estimated parameters of von Bertalanffy growth model are mentioned in Table 4 and represented in Figure 4.

Table 4

Estimates von Bertalanffy growth parameters TL_∞, W_∞, k and t_0 for females, males, and combined sex of *R. alba* in the Gulf of Gabes.

Sex	TL_∞ (cm)	W_∞ (kg)	k ($year^{-1}$)	t_0 (year)
Females	202.26±3.40	144.86	0.040±0.038	1.84±0.01
Males	198.60±3.61	105.57	0.060±0.076	1.28±0.04
Combined sex	200.40±3.57	125.22	0.050±0.020	1.47±0.04

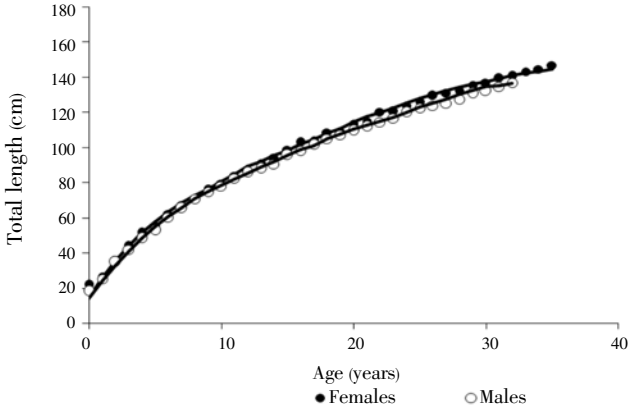

Figure 4. Von Bertalanffy growth curves for *R. alba* by length at age data.

4. Discussion

This is the first known research made on age reading of *R. alba*. The average length values of these rays were between 52.18 and 76.22 cm. The longest male and female measured 150 and 160 cm in TL, respectively, Males *R. alba* attained a smaller maximal size than females confirming the sexual dimorphism in skates[15].

TL and total mass relationships were significantly different between the sexes. But Ebert *et al.* did not reveal significantly difference of this species[16]. The difference between sexes was found for several skates[17,18]. Females reach larger body sizes than males as a consequence of body space needed for egg production and storage during the reproductive stage[18]. According to the "b" values obtained for both sexes, the females and males of the species showed a positive growth characteristic.

The relationship between animal length and RV suggests that *R. alba* vertebrae continue to grow throughout life, making them a suitable structure for estimating age and investigating growth. In fact, these structures were used frequently for age determining[19–21].

There are various approaches for verifying age estimation methods of which edge analysis and MIR are among the most frequently employed. In this study MIR was calculated. These methods focus on incremental patterns of growth–band pairs throughout the year. The annual periodicity in band pair formation observed in the Gulf of Gabes is supported by other species[19–21]. The values of the IAPE and the CV suggested that the precision levels obtained are according to the reference point values indicated by Duman and Başusta[7].

Values of L_∞ determined in our work revealed that adult females grew larger than did adult males, whereas the value of k for males was higher than that for females. Male growth rates tended to be faster, which is in agreement with the results of previous studies for other rajid species[7,13,22].

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgements

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Comments

Background

The submitted manuscript provides new and relevant data about the length distribution, sex ratio, length weight relationship, age and growth of *R. alba* in the Gulf of Gabes.

Research frontiers

The stated purposes for this study were to provide an effective tool for fishery biologists, managers and conservationists to initiate management strategies and regulations for the sustainable conservation of the remaining stocks of this species in Southern Tunisian waters and elsewhere in the region.

Related reports

The white skate, is distributed in the Eastern Atlantic

from the British Isles southward, also along the coast of Africa and in most of the Mediterranean (to Tunisia and Turkey). In spite of the increasing fishing pressure, there is a paucity of information on white skate life history resulting in an assessment of 'critically endangered' on IUCN Red List assessments for Chondrichthyans in the Mediterranean Sea.

Innovations and breakthroughs

The study is original in the region. Results derived from this study provide important and useful information for conservation and management of this species.

Applications

This study would be an effective tool for fishery biologists, managers and conservationists to initiate management strategies and regulations for the sustainable conservation of the remaining stocks of this species in the Gulf of Gabes (Southern Tunisia) ecosystem.

Peer review

This manuscript provides basic information about some biological parameters of *R. alba* in the Gulf of Gabes. The stated purposes for this study were to provide an effective tool for fishery biologists, managers and conservationists to initiate management strategies and regulations for the sustainable conservation of the remaining stocks of this species in Southern Tunisian waters and elsewhere in the region. The manuscript advances relevant contributions to these themes and provides some inconsistencies and omissions can be resolved. I recommend its publication in Journal of Coastal Life Medicine.

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