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Age and growth estimates of thornback ray, *Raja clavata* (Linnaeus, 1758) in Western Algerian coast (Chondrichthyes, Rajidae)

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Abstract

Skates (order Rajiformes) are the most diverse group of Chondrichthyan fishes, due to their high diversity, and global distribution, our knowledge of skate biology and ecology remains limited. The objective of the present study was to assess the population dynamics of *Raja clavata*, particularly to provide the relationships between morphometric and biometric characters, then to investigate age and growth. For this propose, Thornback ray were investigated using 563 specimens, females made up 59.85% and males 40.14%. Weight-Lengths Relationships (WLRs) described by the relative growth, were determined according to the allometric equation revealed the following results: Weight-total length, $W_T = 0.003\ L_T^{3.16}$, $W_T = 0.004\ L_T^{3.10}$ and Weight-disc width; $W_T = 0.012\ D_W^{3.13}$, $W_T = 0.007\ D_W^{3.28}$, therefore parameters relationships between length-disc width evaluated by linear equation were ; $D_W = 0.662\ L_T + 0.41$, $D_W = 0.634\ L_T + 2.94$ respectively for females and males. The parameters of the Von Bertalanffy growth equation obtained using the software LFDA (subroutine ELEFAN)for females were; $L_\infty = 105$ cm, $k = 0.46$, $t_0 = -0.20$, for males; $L_\infty = 100$, $k = 0.35$, $t_0 = -0.68$.This research will provide a starting point for the development of a management plan and stock assessment of *Raja clavata* carried in Algerian coast, and results obtained are important input data to better understanding its role in marine ecosystem.

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Introduction

As a group, Skates can be classified as equilibrium (K-selected) strategists and typically share the biological characteristics of low fecundity, late maturity, high juvenile survivorship, slow body growth, and long life span (Hoenig and Gruber, 1990; Camhi *et al.,* 1998). Equilibrium strategists tend to have slow rates of population growth and generally cannot sustain high levels of fishing pressure (Holden, 1974; Adams, 1980).

Rajiformes represent one of the most important orders of elasmobranch fish occurring in the north-eastern Atlantic and Mediterranean, both by the number of species and by economic importance, therefore many authors have recognized the ecological importance of the Rajidae and have carried out studies on its biology, for growth rates are estimated from tagging data (Holden, 1972), by length frequency analysis (Brander and Palmer, 1985), growth increments (Holden and Vince, 1973; Ryland and Ajayi, 1984), ages are also assessed by(Taylor and Holden, 1964; Fahy, 1989; Whittamore and McCarthy, 2005), and other various aspects on the population dynamics and reproduction are provided (Quéro and Gueguen, 1981; Stehmann, 2002; Morato*et al.,* 2003;Bradaï *et al.,* 2004; Demirhan *et al.*, 2005; Gallagher *et al.,* 2005; Serra-Pereira *et al.,* 2005b; Capapé *et al.,* 2006, 2007).

Scientific concern about the sustainability of Rajidae populations have lead to several studies of the population biology and distribution of *R. clavata* in British waters (Quero *et al.,*1981; Ellis *et al.,* 2005; Whittamore and McCarthy, 2005; Chevolot *et al.,*2006), North Sea (Walker, 1998), Irish Sea (Dulvy *et al.,* 2000; Gallagher *et al.*, 2004), in the Black Sea(Saglam and Orhan, 2010), studies done in the Mediterranean were focused on abundance and biomass of *R. clavata* in Adriatic Sea (Jardas, 1973; Jukic *et al.,*2001), Gulf of Lion (Capapé *et al.*, 2000), Italian waters (Relini *et al.*, 2000), Balearic Islands (Massuti and Moranta, 2003), Strait of Sicily (Garofalo *et al.,* 2003) Tunisian sea (Mnasri *et al.*, 2009; Kadri *et al.*, 2013, 2014), and in Algerian basin (Dieuzeide *et al.*, 1953, 1958 ; Massuti *et al.*, 2003, 2004, Hemida, 2005 ; Hemida *et al.,* 2007 ; Refes, 2007).

Studies on biology and ecology aspect of Thornback ray in the Algerian coast are very scarce, therefore the aim of our study is to define several biological characteristics, such as structure of population, relationships between weight and size, biometric growth and provide parameters of growth and age of this species in study area. These informations are essential to understanding the population dynamics and resilience of this species to exploitation.

Materials and methods

In the present study, a total of 563 individuals of thornback ray, 337 females and 226 males were collectedbetween January to December 2012 by otter trawls during investigations conducted off oranian bay (south-western Mediterranean), Geographic coordinates of our study area are: 00°39'09" latitude north 35°43'00" longitude west(Fig.1). Species were identified as *Raja clavata* following (Tortonese, 1956; Quignard, 1965; Aloncle, 1966; Quéro *et al.,* 2003; Hemida, 2005).

Sex ratio and population structure

In our study, the size frequency was analyzed at a 3cm interval standard length class. The sex ratio was analyzed by using a Chi-square test. We calculated parameters a andb ofthe relationship between weight to total length and disc width (WLRs) applying the following equation:$W_T = a\ L_T^b$ (Le Cren, 1951).An allometric coefficient b value larger or smaller than 3.0 shows an allometric growth, or isometric growth when it is equal to 3.0 (Bagenal and Tesch, 1978).The degree of association between the variables of this exponential regression was computed by the determination of coefficient r^2, and to define the relationship between total length and disc width we have used the linear equation: $D_W = a\ L_T + b$.

Growth was expressed in terms of the Von Bertalanffy equation (1938) (Beverton and Holt, 1957):

$L_T = L\infty\ (1\text{-}e^{-K\,(t-t_0)})$.

Fig. 1. Study area: Western Algerian coast.

where: **L∞**: the asymptotic total length, **LT**: the total length at age t, **K**: the growth curvature parameter and **t0**: the theoretical age when fish would have been at zero total length, in our study, we used a numerical method, the method ELEFAN (electronic length frequency analysis) (Pauly and Moreau, 1997). For mathematical modeling, the LFDA software was used (Kirkwood *et al.*,2001).

Analyses were made for males and females, separately.

Results

Thornback ray caught in oranian coast were examined, of which 337 were females ranging from 25.5 to 83.8 cm and 226 were males ranging from 29.9 to 80.2 cm total length.

Table 1. Morphometric characters of*Raja clavata*in Algerian coast.

	Females			Males		
	LT	DW	WT	LT	DW	WT
Max	82.9	56.2	3800	80.2	52.9	3500
Min	25.5	17	110	29.9	15.6	120
Mean	54.2	36.6	1955	55.05	34.25	1810

The sample size; minimum (Min), maximum (Max), mean lengths and weights made on *Raja clavata* are shown in Table 1. We observed that mean total length disc width WD and weight were greater for females than that for males. Therefore, females were larger and heavier than the males.

Sex-ratio

Histograms illustrate length-frequency distributions by sex of thornback ray (Fig.3) revealed that the bulk of samples indicated that a peak occurred at a size of 42.5 - 48.5 cm LT for both of sex.

The sex ratio showed a predominance of females, the catch rate 40.14% for males and 59.85% for females.

Size-weight relationships

The length-weight and disc width-weight relationships showed similar values of **b** for females and males, both >3, this coefficient had a higher value

for females than for males. Weight-Lengths Relationships (WLRs) of thisspeciesindicate a positive allometry in the relative growth for both of sex (Fig.4 and 5), therefore we can say that weight of thornback ray increases with growth which is evident by coefficients governing the morphometric characters relationship curves according to:

$W_T = a\ L_T^b$. Data concerning size-weight relationships between sexes and sex combined are presented in Table 2.

Table 2. Parameters of biometric characters of thornback ray in western basin of Algeria.

	Weight-	Total Length		Weight	-Disc Width	
Parameters	a	b	r^2	a	b	r^2
Females	0.003	3.165	0.97	0.012	3.13	0.96
Males	0.004	3.11	0.97	0.011	3.18	0.95
Both of sex	0.003	3.149	0.97	0.011	3.15	0.96

Table 3. Parameters of morphometric characters of thornback ray in western basin of Algeria.

	Total Length- Disc Width relationship		
Parameters	a	b	r^2
Females	0.66	0.40	0.99
Males	0.62	2.22	0.97
Both of sex	0.64	1.13	

Morphometric parameters

On the other hand, Relationship between total length (L_T)-disc width (D_W) show also a positive allometric growth (Fig.6) for males and females of *Raja clavata* sampled in oranian coast (North western Mediterranean). Results shown in Table 3 revealed that W_D is positively correlated with L_T for both of sex.

Table 4. Summary of biometric and morphometric relations of the Mediterranean thornback ray in western basin of Algeria.

Parameters	Weight -Total Length (r^2)	Weight - Disc Width (r^2)	Width -Total Length (r^2)
Females	$W_T = 0.003^* L_T^{3.165}$ (0.97)	$W_T = 0.012^* D_W^{3.13}$ (0.96)	$D_W = 0.66^* L_T + 0.40$(0.99)
Males	$W_T = 0.004^* L_T^{3.11}$(0.97)	$W_T = 0.011^* D_W^{3.18}$ (0.95)	$D_W = 0.62^* L_T + 2.22$(0.97)
Both of sex	$W_T = 0.003^* L_T^{3.149}$(0.97)	$W_T = 0.011^* D_W^{3.15}$ (0.96)	$D_W = 0.64^* L_T + 1.13$(0.98)

Growth study

The adjustment of growth parameters in Von Bertalanffy model shows that the values differ significantly between the sexes:

$Lt = 105\ (1\text{-}e^{-0,46(t\ +\ 0,20)})$ and $Lt = 100\ (1\text{-}e^{-0,35(t\ +\ 0,68)})$with higher values of growth coefficient K: 0.46 $year^{-1}$ and $L\infty$: 105 cm for females.

Results obtained in our investigation (Table 5 and 6) revealed that the growth of *Raja clavata* of sample on the west coast of Algeria for each sex decreases with age (Fig.2).

Discussion

Population structure

The status of Mediterranean thornback ray is still poorly known, the findings reported in this study represent the first data of *Raja clavata* caught in south western Mediterranean.

Maximum total length observed for females and males 82.9 and 80.2 cm respectively were slightly different to sizes reported in other studies (Demirhan *et al.,* 2005; Capapé *et al.,* 2006, 2007; Serra-Pereira

et al., 2012; Bottari *et al.,* 2013; Kadri *et al.,* 2014). The reason of differences between values given by different authors could be attributed to samples collected from different areas and depths and the selectivity of sampling gears, or may be relatedto the differences in sampling times and sampling methods, because in the other studies, fish were caught by bottom trawls, purse seiners, gillnet or trammel nets, these fishing methods are able to catch every size of thornback rays.

Table 5. Growth parameters of *Raja clavata* females and males.

Sex		Females			Males	
Parameters	K	L∞	t_0	K	L∞	t_0
Results	0.46	105	-0.20	0.35	100	-0.68

Table 6. Von Bertalanffy Equation.

	Von Bertalanffy equation
Females	$Lt = 105\ (1\text{-}e^{-0,46(t + 0,20)})$
Males	$Lt = 100\ (1\text{-}e^{-0,35(t + 0,68)})$

Sex ratio

The study of sex ratio shows the dominance of female individuals in favor of females, our results are in agreement with many authors who have described the Rajidae in other Mediterranean sea areas (Capapé *et al.,* 2007, Kadri *et al.,* 2014), and in the Southeastern Black Sea (Demirhan *et al.,* 2005), but we noted adifference of values of the catch rate in favor of males in studies reported in Irish Sea (Gallagher *et al.,* 2004), these differences in sex ratio may be a consequence of behavior, because many species segregate by sex, size, and maturity (Holden, 1975).

Table 7. Summary of parameters growth equation for *Raja* clavata in different areas.

Authors	Sex	L∞	K	t_0	Areas
Taylor and Holden, 1964	F	127.3	0.10	-2.50	British waters
	M	88.3	0.22	-1.30	
Holden, 1972	F	128.1	0.09	-1.32	Irish Sea, Bristol Channel
	M	85.6	0.21	-0.60	
Ryland and Ajayi, 1984	Both of sex	139.2	0.09	-2.63	Bristol Channel
Brander and Palmer, 1985	Both of sex	105	0.22	-0.45	Irish Sea
Walker, 1998	F	118	0.14	-0.88	North Sea
	M	98	0.17	-0.43	
Whittamore and McCarthy, 2005	F	117.6	0.16	-0.71	North Wales
	M	100,9	0.18	-0.99	
Serra pereira, 2005	F	130.5	0.10	-0.13	Portuguese waters
	M	121.5	0.11	-0.11	
	Both of sex	130.5	0.10	-0.14	
Serra pereira, 2010	F	140,7	0.097	- 0.88	Portuguese waters
	M	117,1	0.14	- 0.35	
Kadri *et al.*, 2013	F	114.6	0.11	-1.23	Tunisian coast
	M	100.8	0.14	-1.13	
Present study 2017	F	105	0.46	-0.20	Algerian coast
	M	100	0.35	-0.68	

Table 8. A comparative table of Biometric characters of *Raja clavata*.

Authors	Sex	A	B	Areas
Ryland and Ajayi, 1984	Females	0.0084	3.30	Bristol Channel
	Males	0.0019	3.17	British Ishles
Dorel, 1986	Undefined	0.0032	3.19	Atlantique North-east
Merella *et al.,* 1997	Sex combined	0.0024	3.20	Balearic Islands (Mediterranean Sea)
Dorel *et al.,* 1998	Males	0,0026	3,23	Manche
	Sex combined	0,0031	3.19	
Düzgünez *et al.,* 1999	Sex combined	0.003	3.18	East Black Sea
Filiz and Mater, 2002	Females	0.0018	3.23	North Aegean Sea, Turkey
	Males	0.0006	3.56	
Demirhan *et al.,* 2005	Females	0.0003	3.69	Black Sea
	Males	0.005	3.02	Southeastern Black Sea
	Sex combined	0.001	3.42	
Krstulovic *et al.,* 2009	Females	0.0011	3.42	Black sea northern and central Adriatic
	Males	0.0012	3.39	Sea
Kadri *et al.,* 2014	Females	0.0011	3.40	Gulf of Gabes (Tunisia)
	Males	0.0017	3.26	Mediterranean Sea.
Adda-hanifi *et al.,* 2017	Females	0.003	3.16	Oranian bay (Algeria)
	Males	0.004	3.10	Mediterranean Sea.

Length-weight relationships

We also found, that Biometric parameters of relative growth, defined size weight relationships showed positive allometry of males (b = 3.11) and females (b = 3.165).

Results obtained on length weight relationships for *R. clavata* of Algerian coast presented in Table 2 and 4 were similar to those found in other Mediterranean areas, such as the Balearic Islands (Merella *et al.,* 1997), Manche (Dorel *et al.,* 1998)Gulf of Gabes (Kadri *et al.,* 2014) and lower than those in Bristol Channel (Ryland and Ajayi, 1984), North Aegean Sea (Filiz and Mater, 2002) and the Adriatic Sea (Krstulovic *et al.,* 2009) (Table 8).

We also observed that the functional regression b-values of Weight -Disc width relationships for males, females and sex combined were greater than '3'. (Table 2 and 4) these results were agrees with study done in Black Sea (Demirhan *et al.,* 2005).

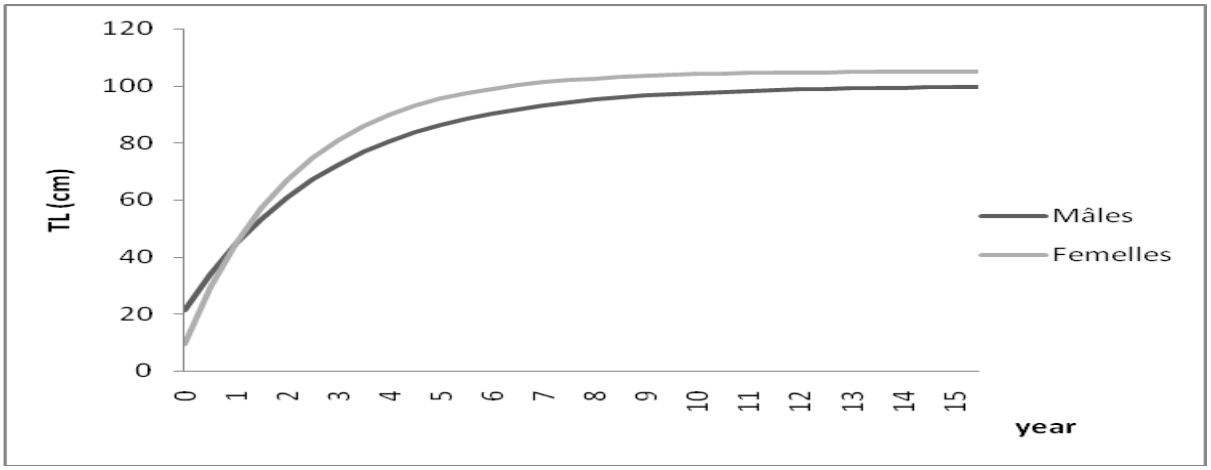

Fig. 2. Von Bertalanffy growth curves for male and female of *Raja clavata* from west Algeria.

The difference between sex characters in our results indicating faster weight increase in females in relation to length is in accordance with results of previous studies in Mediterranean and other areas (Mendes *et al.,* 2004; Demirhan *et al.,* 2005; Bottari *et al.,* 2013). Differences in growth between sexes are a common feature in *Raja* sp.various factors may be responsible for the similar or different biological parameters, such as temperature, salinity, feeding (quantity and quality, sex and maturity stage. In addition, changes in physiological conditions, can all affect the **b** growth exponent (Le Cren, 1951).

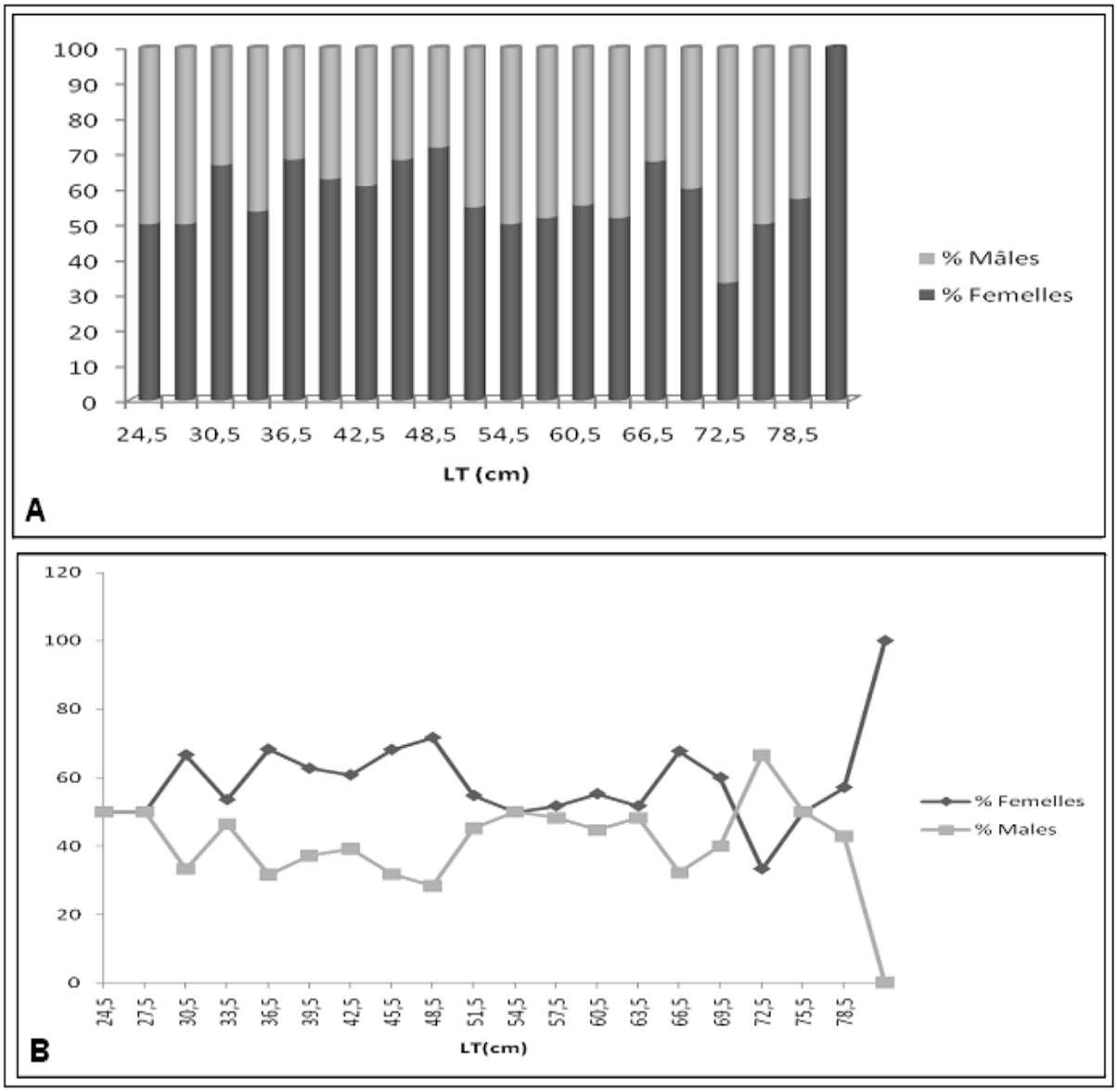

Fig. 3. Sex ratioof *Raja clavata* in Algerian coast, **A:** Histogram of Length frequency distribution, **B:**Distribution of males and females.

Length-Width relationships

Moreover, we have shown that the parameter **a** of size-width relationships (Table 3 and 4) estimated by linear regression in the present study recorded for thornback ray was slightly greater than the values estimated in Cantabrian Sea (Fernandez *et al.,* 2001) but it was in accordance with a study done in Southeastern Black Sea (Demirhan *et al.,* 2005;Krstulovic *et al.,* 2009).

Growth study

The VBGF produced more reliable growth parameters, considering the life history of the studied species.

We observed that VBGP estimated for thornback ray caught in Western coast of Algeria (Table 5 and 6) are different from those estimated in other areas from Irish Sea (Holden, 1972; Brander and Palmer, 1985; Fahy 1989) Irish Sea and Bristol Channel, (Dorel *et al.*,1998) gulf of Gascogne,(Walker 1998), North Sea (Whittamore and McCarthy, 2005), Portuguese waters (serra Pereira, 2010) (Table 7).

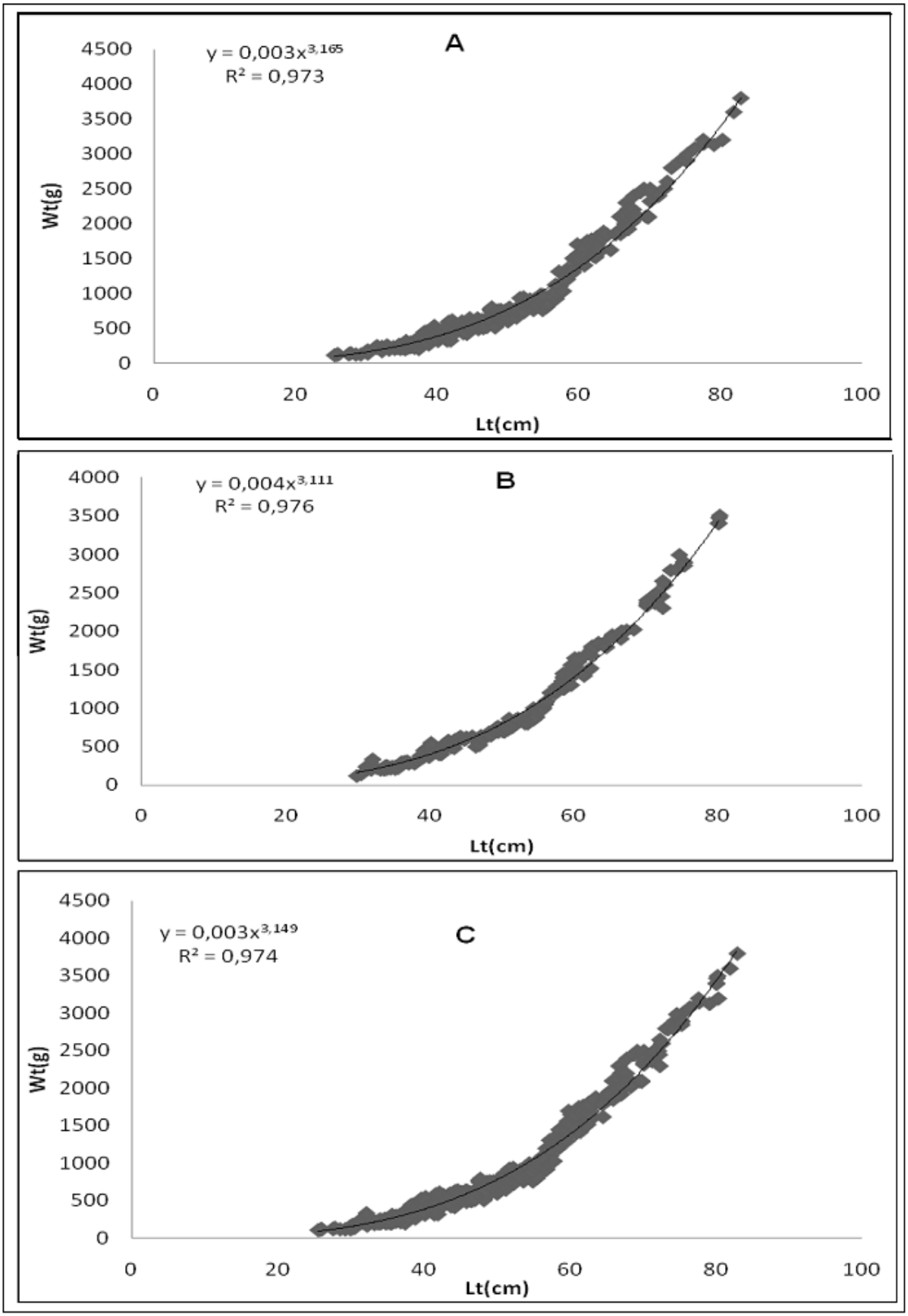

Fig. 4. Weight-Length relationships of *Raja clavata* caught in oranian bay (Algeria)A: Females, B: Males, C: sex combined.

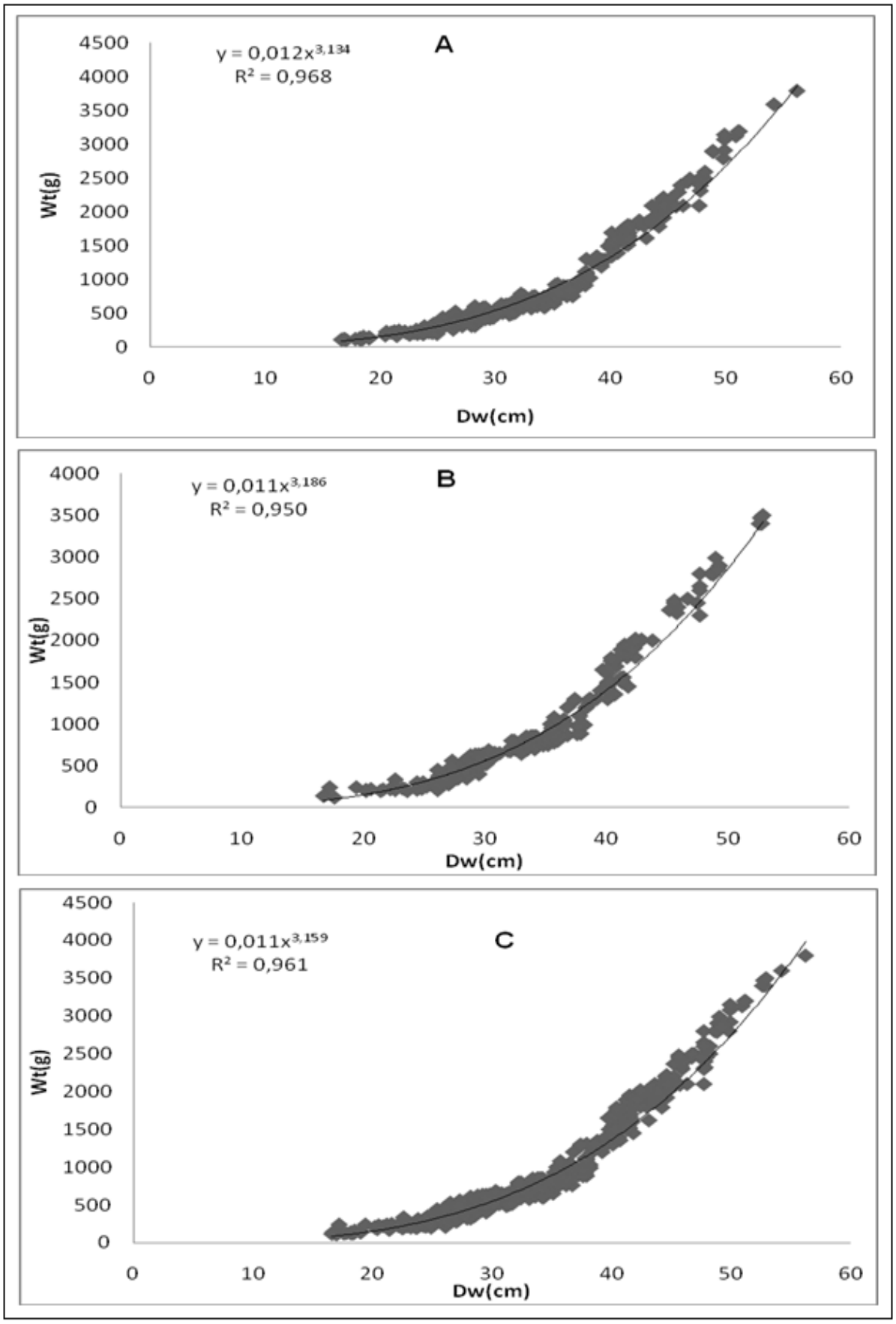

Fig. 5. Weight-Width relationships of *Raja clavata* caught in oranian bay (Algeria).A: Females, B: Males, C: sex combined.

The observed differences in growth model parameters between these studies may be due to several factors; sampling methods, locations, the age classes included in the models (Yigin and Ismen, 2012; Serra Pereira, 2005),this discrepancy could also be derived from other factors that may be affecting the growth of species, such as environmental differences between the Mediterranean and Atlantic Ocean, the influence of water temperature, species behavior and different exploitation state.

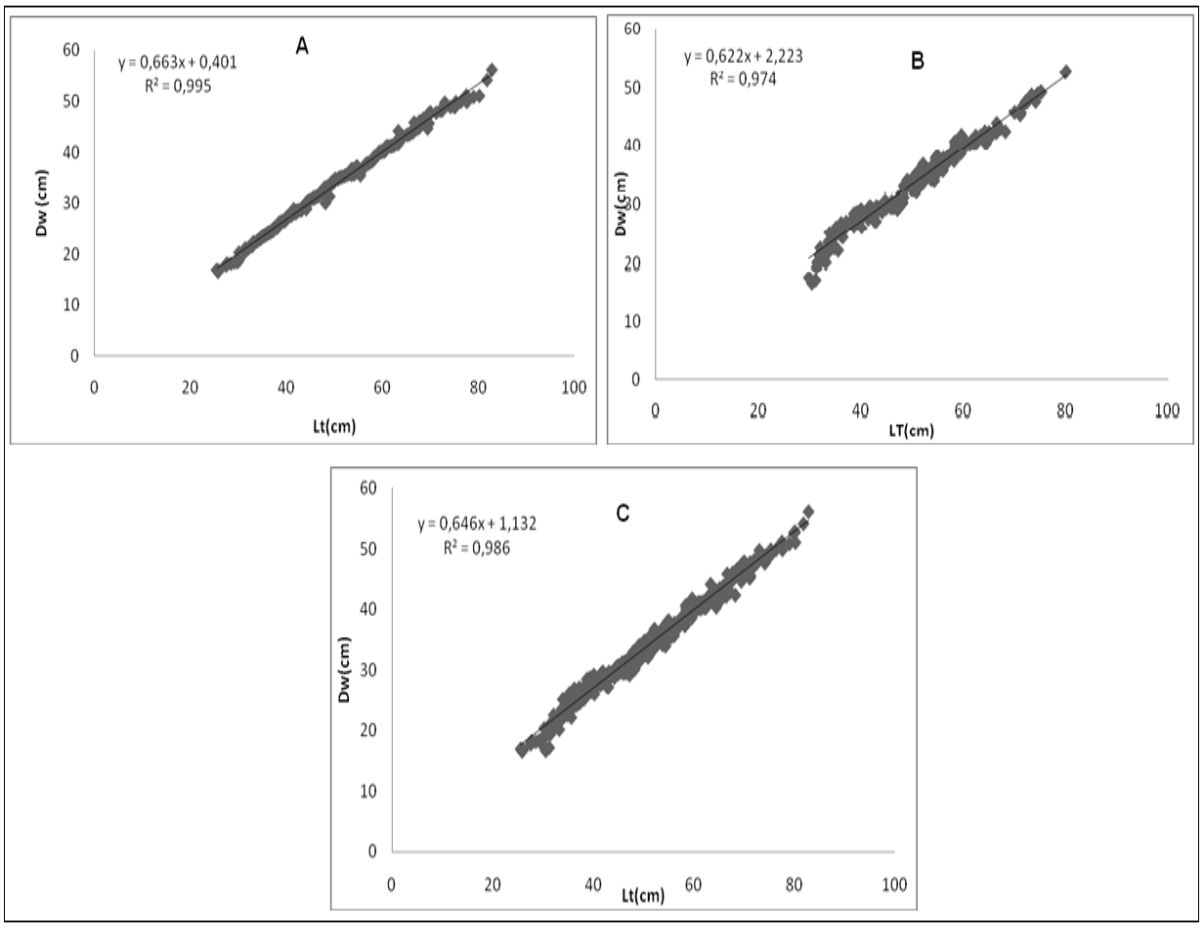

Fig. 6. Relationships between total length and disc width of *Raja clavata* in Oranian bay (Algeria) A: Females, B: Males, C: sex combined.

Conclusion

In conclusion, this investigation was a response to a lack of knowledge of the biology of *Raja clavata* carried in Algerian coast. The length-mass relationships were described by the equation: W_T = 0.003* L_T $^{3.165}$and W_T = 0.004* L_T $^{3.11}$, therefore, values of "a" and "b" of width-mass relationships are presented also by the relation of relative growth: W_T = 0.012* D_W $^{3.13}$ and W_T = 0.011* D_W $^{3.18}$ respectively for females and males.

The Von Bertalanffy growth equations obtainedto determine the age according to the size were:

$Lt = 105\ (1\text{-}e^{-0,46(t + 0,20)})$ for females and

$Lt = 100\ (1\text{-}e^{-0,35(t + 0,68)})$ for males.

Results from this research will provide a starting point for the development of a management plan for the thornback ray in harbor of western coast of Algeria. Further investigations are necessary to quantify the impact of the existing regulations on the population dynamics and recruitment patterns of this species in the region.

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