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THE GROWTH AND REPRODUCTION OF TWO SPARIDAE, *PAGRUS CAERULEOSTICTUS* AND *PAGELLUS BELLOTTII* IN NORTHERN MAURITANIAN WATERS (EASTERN TROPICAL ATLANTIC)

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ABSTRACT

The paper presents the growth and reproduction parameters for two Sparidae fish species studied in the coasts of northern Mauritania during 2020. The parameters were obtained using a total of 450 indiv. of Pagrus caeruleostictus and 516 indiv. of Pagellus bellottii. The male to female ratio was 52.1% to 47.9% in P. caeruleostictus and 53.2% to 46.8% in P. bellottii. Sex products were observed from August to October for P. caeruleostictus. The spawning period extended from July to December for females and from August to November for males of P. bellottii, with a lag of one month between the sexes. Length at sexual maturity in P. caeruleostictus was 28.4 cm for males and 28.6 cm for females; and in P. bellottii 20.04 cm for males and 19.6 cm for females.

Key words: *Pagrus caeruleostictus*, *Pagellus bellottii*, growth, reproduction, Mauritania

CRESCITA E RIPRODUZIONE DI DUE SPARIDI, *PAGRUS CAERULEOSTICTUS* E *PAGELLUS BELLOTTII*, NELLE ACQUE DELLA MAURITANIA SETTENTRIONALE (ATLANTICO TROPICALE ORIENTALE)

SINTESI

L'articolo presenta i parametri di crescita e riproduzione di due specie di Sparidi delle coste della Mauritania settentrionale, studiati durante il 2020. I parametri sono stati ottenuti utilizzando un totale di 450 individui di Pagrus caeruleostictus e 516 individui di Pagellus bellottii. Il rapporto maschi/femmine era di 52,1%-47,9% in P. caeruleostictus e 53,2%-46,8% in P. bellottii. Le cellule sessuali sono state osservate da agosto a ottobre per P. caeruleostictus. Il periodo di deposizione delle uova si estende da luglio a dicembre per le femmine e da agosto a novembre per i maschi di P. bellottii, con un ritardo di un mese tra i due sessi. La lunghezza alla maturità sessuale in P. caeruleostictus era di 28,4 cm per i maschi e 28,6 cm per le femmine; in P. bellottii 20,04 cm per i maschi e 19,6 cm per le femmine.

Parole chiave: *Pagrus caeruleostictus*, *Pagellus bellottii*, crescita, riproduzione, Mauritania

INTRODUCTION

Knowledge of fishery resources requires the study of its two components (fish biotopes and biocenosis). The bluespotted seabream, *Pagrus caeruleostictus*, is one of the Sparidae species (Orrell et al., 2002). It is commonly found in the Eastern Atlantic and in the Mediterranean Sea (Bauchot & Hureau, 1986; Fischer et al., 1987) at depths ranging from 30 to 200 m (Schneider, 1990; Ismail et al., 2018).

The red pandora (*Pagellus bellottii*) occurs in schools over hard and sandy bottoms, mainly in the upper 100 m. Omnivorous with a predominantly carnivorous diet (including crustaceans, cephalopods, small fish, amphioxii, and worms). Eastern Atlantic from the Strait of Gibraltar to Angola, including the Canary Islands, and southwestern Mediterranean (Bauchot & Hureau, 1986).

The percentages of captures of the two studied species versus other commercial species in the area are 3–5 % depending on the year (Belhabib et al., 2012; Marti, 2018).

Particularly in Mauritania, biological studies on these two species are rather outdated (see Navarro et al., 1943; Ikeda & Tetsuya, 1971; Dia et al., 2000a & 2000b; Ould Yarba et al., 2004; Soukhovershin & Ly, 1978–1979; Ndiaye, 2014), hence the need to revise the data. Spawning patterns and reproductive strategy of fish have been mainly considered as part of research aimed at managing the fisheries (Chakroun-Marzouk, 1985; Chakroun Marzouk et al., 1987; Barry et al., 2003 and 2004; Alonso-Fernandez et al., 2008; Ismail et al., 2018).

The size at first sexual maturity is an important parameter for population dynamics as it allows for estimations about the contribution of small fish to the reproduction potential of the stock, about the non-reproductive female composition of samples, and about how to avoid premature captures which can adversely affect reproduction. It should be taken as the absolute minimum catch size for a rational exploitation of the stocks.

This study aims to update data on the growth and reproduction of two Sparidae species, *Pagrus caeruleostictus* (Valenciennes, 1830) and *Pagellus bellottii* (Steindachner, 1882), caught along the Mauritanian coast.

MATERIAL AND METHODS

Both fish species were sampled in the artisanal port of Nouadhibou (NDB) and also collected during sea campaigns for monthly monitoring of the octopus *Octopus vulgaris* by the research vessel Al Awam in the area comprised between 16°40'–17°00'W and 19°10'–21°00'N (Fig. 1).

A total of 450 specimens of *P. caeruleostictus* and 516 specimens of *P. bellottii* were collected from January to December 2020 (ca. 40 specimens per species per month). Individual fish were weighed to the nearest gram (total weight), and total length (TL) and fork length (FL) to the nearest cm. The liver and the gonads were removed and weighed to the nearest 0.01 g using a precision balance (type AE-ADAM STB 62021) and the degree of sexual maturity was determined. After evisceration, each individual carcass was weighed.

Changes in gender percentages (sex ratio) for males and females were calculated for each species. The results were tested by the χ^2 test. Reproduction and growth parameters were studied from January to December 2020. Equation parameters a and b of the height-to-weight relationship ($TW = a * FL^b$) and the relationship between total length and fork length were established for each sex and for both species.

Sexual maturity was determined according to the macroscopic appearance of the gonads using the Mann and Buxton scale (1998). The sexual cycle of each species was followed through the development of its gonadosomatic index (GSI) calculated according to the formula: $GSI = (GW \times 100) / EW$, where GW = mass of the gonad, and EW = mass of eviscerated fish.

The development of the GSI over time (January to December 2020) enabled the identification of the species' reproductive period. Size at first sexual maturity (L50) was determined using R software and the "FSA,"

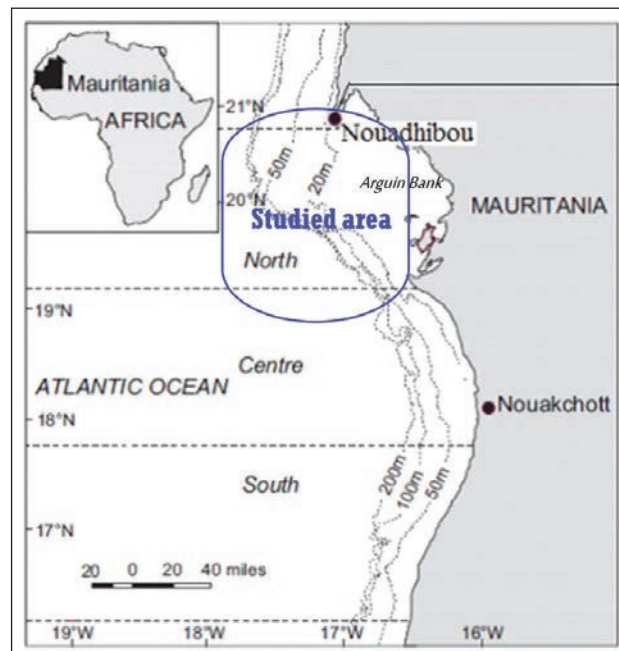


Fig. 1: The coastal region of Mauritania with the study zone (blue box insert).

Sl. 1: Obrežni predel Mavretanije z označenim obravnavanim območjem (modri kvadrat).

Tab. 1: Parameters of the length-weight relationship by species and by sex. TW = Total weight of the individual, EW = eviscerated weight, FL = fork length, (a and b) = parameters of the equation.**Tab. 1: Parametri dolžinsko-masnega odnosa pri obeh vrstah in spolih. TW = celokupna masa primerka, EW = masa brez drobovja, FL = dolžina do vilice, (a in b) = parametri v enačbi.**

Species	Sex	TW = a*FL ^b	R ²	N
<i>Pagrus caeruleostictus</i>	Male	TW = 0.0004FL ^{2.89}	0.92	234
		EW = 0.00006FL ^{2.81}	0.91	234
	Female	TW = 0.00007FL ^{2.81}	0.93	215
		EW = 0.00007FL ^{2.79}	0.93	215
<i>Pagellus bellottii</i>	Male	TW = 0.0002FL ^{2.971}	0.88	267
		EW = 0.00001FL ^{3.07}	0.94	267
	Female	TW = 0.0001FL ^{3.08}	0.86	235
		EW = 0.00008FL ^{1.74}	0.85	235

Tab. 2: Total length vs. fork length relationship by species and by sex.**Tab. 2: Odnos med celotno dolžino in dolžino do vilice pri obeh vrstah in spolih.**

Species	Sex	A	b	N	R ²
<i>Pagrus caeruleostictus</i>	Males	1.46	0.95	234	0.96
	Females	1.41	0.96	215	0.97
	Indeterminate			1	
	Total of specimens			450	
<i>Pagellus bellottii</i>	Males	1.21	0.98	266	0.94
	Females	1.73	0.92	234	0.95
	Indeterminate			16	
	Total of specimens			516	

“FSAdat” and “CAR” packages. Size L50 corresponds to the fork length at which 50% of individuals in the population are mature. The growth parameters (L_{∞} and K) of the two species were obtained by incorporating frequency into the R software and using the “TropFishR” package. This package is based on the FISAT II technique, which uses the Electronic Length Frequency Analysis (ELEFAN) method; it is a system of stock assessment methods based on length frequency (LFQ) data from restructured LFQ data. This method is used to estimate the parameters of the growth model from the progression of LFQ modes over time accord-

ing to the Von Bertalanffy growth function (VBGF). It is based on the use of the functions available in ELEFAN.

K is the growth curvature parameter, and t_0 is the theoretical age of fish at zero total length.

RESULTS

Length-weight relationship

The sex and weight relationships in these two fish species show quite high correlation coefficients with R-squared value R^2 at 0.85–0.94 for *P. bellottii*

Tab. 3: Size structure (FL) by sex for *Pagrus caeruleostictus*.**Tab. 3: Velikostna struktura (FL) po spolu za vrsto *Pagrus caeruleostictus*.**

FL (cm)	♀	♂	Total	χ^2 ♀	χ^2 ♂	χ^2 Total
22-24	2	3	5	0.06	0.06	0.12
25-27	23	25	48	0.00	0.00	0.00
28-30	75	84	159	0.02	0.02	0.03
31-33	69	73	142	0.01	0.01	0.03
34-36	35	34	69	0.12	0.11	0.22
37-39	8	12	20	0.26	0.24	0.50
40-42	3	3	6	0.01	0.01	0.01
Total	215	234	449	0.48	0.44	0.92

Tab. 4: Size structure (FL) by sex for *Pagellus bellottii*.**Tab. 4: Velikostna struktura (FL) po spolu za vrsto *Pagrus bellottii*.**

FL (cm)	♀	♂	Total	χ^2 ♀	χ^2 ♂	χ^2 Total
11—12	1	0	1	0.60	0.53	1.14
13-14	0	3	3	1.40	0.00	1.40
15-16	3	4	7	0.02	0.02	0.04
16-18	9	16	25	0.62	0.55	1.17
18-20	15	38	53	3.88	3.41	7.28
20-22	83	108	191	0.46	0.40	0.86
22-24	83	81	164	0.51	0.45	0.96
24-26	32	15	47	4.55	4.00	8.55
26-28	4	1	5	1.18	1.04	2.21
28-30	4	0	4	2.42	2.13	4.55
Total	234	266	500	15.64	12.53	28.17

and 0.91–0.93 for *P. caeruleostictus* (Tab. 1). It is a large positive linear length-weight association with points close to a linear trend line.

Relationship between total length and fork length

To be able to compare our results with those of other authors, we established conversion equations for the different lengths taken into consideration as a

function of fork length (Tab. 2). The relationship total length (TL) *versus* fork length (FL) was established per species and per sex. The results (Tab. 2) indicate a slightly low allometry. The growth of the fork length is slower than that of the total length, with a coefficient of determination R^2 varying between 0.94 and 0.97, respectively, for the two species. This rigorous connection between these two metric characters allows use of the fork length in the event of failure in the total length measurement.

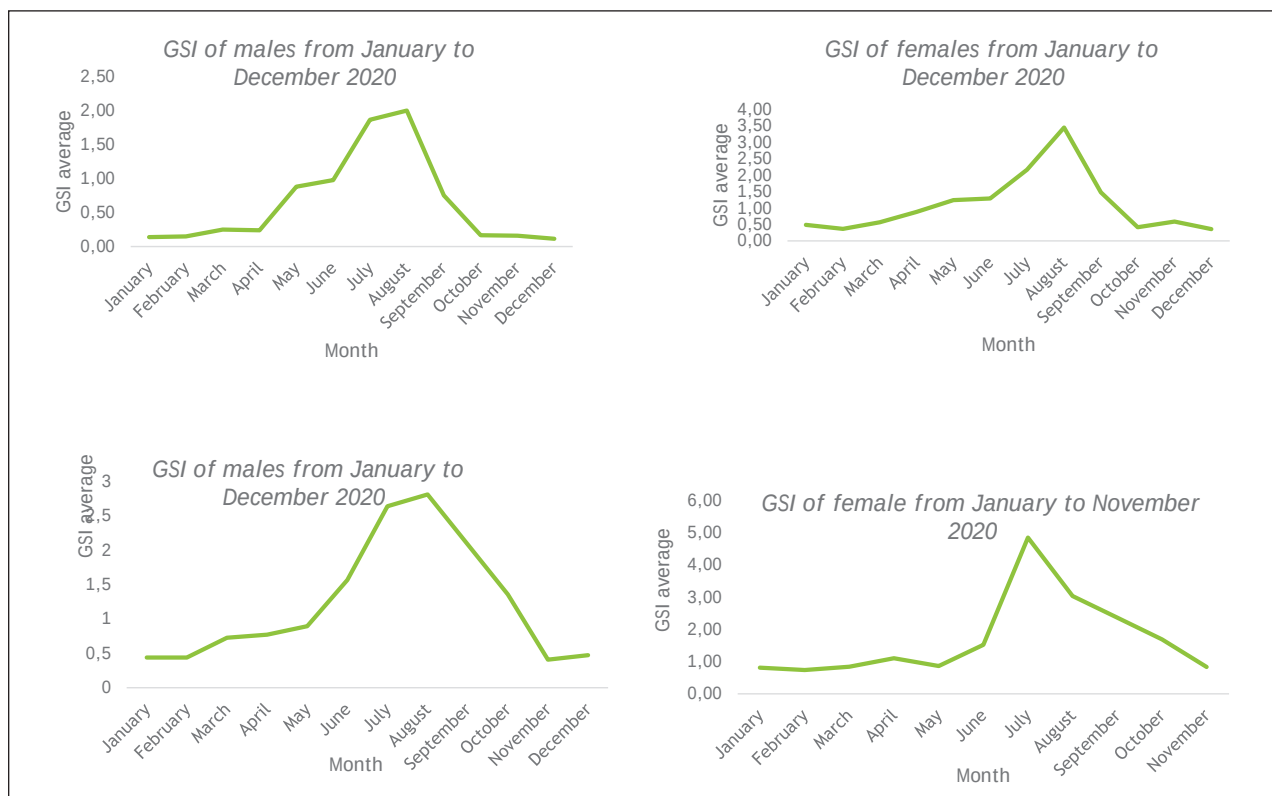


Fig. 2: Monthly evolution of the GSI in *Pagellus bellottii* (top of the graph) and in *Pagrus caeruleostictus* (bottom of the graph).

Sl. 2: Mesečna dinamika GSI pri vrstah *Pagellus bellottii* (vrh diagrama) in *Pagrus caeruleostictus* (spodnji del diagrama).

Sex ratio

The sex ratio is calculated from the total number of individuals collected for each species. In the 450 *P. caeruleostictus* individuals examined, the size varied from 20.6 to 36.5 cm (fork length); 234 specimens were males and 215 females, representing 52% and 48% of the total number, respectively (Tab. 2). In one individual only the sex could not be determined macroscopically. The *P. bellottii* sample was composed of 516 individuals, their size ranging from 14 to 34.8 cm; 266 specimens were males and 234 females, representing 53.2% and 46.8% of the total number, respectively (Tab. 2). The sex could not be determined in 16 individuals. In both species the males outnumbered the females.

Size structure of the two species

To examine the size structure of the two species sampled, χ^2 was applied (Tabs. 3 and 4). The sample size structure analysis of the two species shows that in *Pagrus caeruleostictus* (Tab. 3) there was no significant difference in size between males and females (the calculated $\chi^2 = 0.92$ clearly less than the theoretical

value of χ^2 , 12.59, at the 5% significance level). In *P. bellottii* the difference in size between the two sexes was significant (the calculated $\chi^2 = 28.17$ exceeding the theoretical value of χ^2 , 16.92, at the 5% significance level).

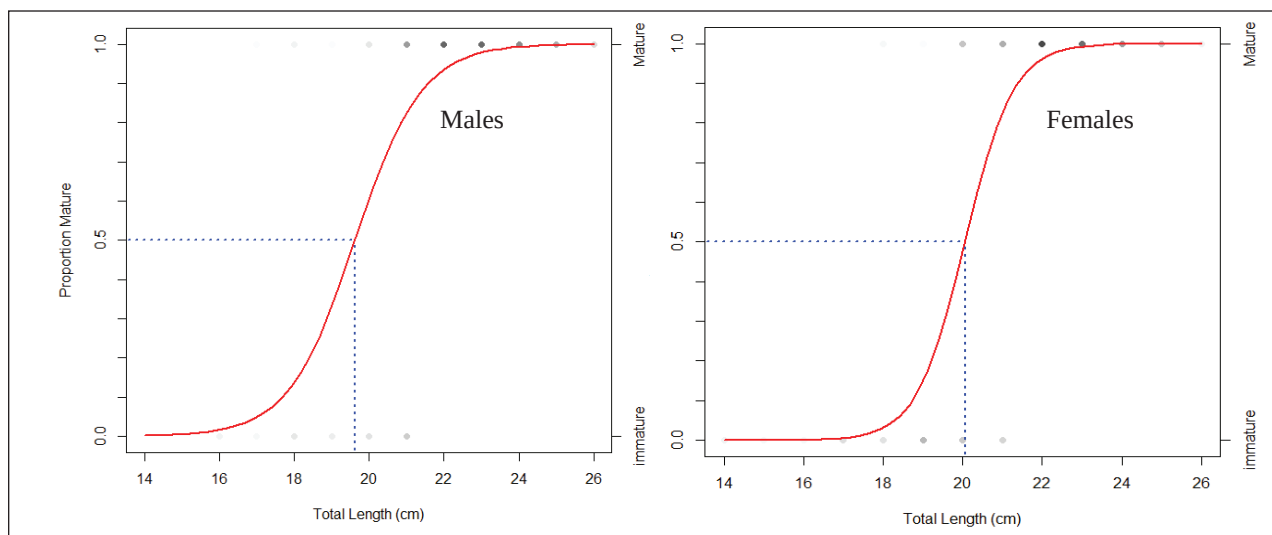
The average size of individuals in a sample can influence its sex ratio; samples containing large specimens most often display a sex ratio favourable to females, conversely, in samples composed mainly of small and medium-sized individuals, males predominate, as was the case with *P. bellottii* (Tab. 4).

Sexual cycle

During the reproduction period, organs, such as the liver and muscles, will provide the energy necessary to maintain the fishes' physiological balance. The reproduction parameters largely control the state of the stock, its renewal and spatio-temporal development. The examination of the monthly variation of the gonadosomatic ratio (GSI) was carried out on a sample of 450 specimens of *P. caeruleostictus* (215 females and 235 males and 1 undetermined) and 516 specimens of *P. bellottii* (234 females, 266 males and

Tab. 5: Summary of the spawning periods for *P. careruleostictus* and *P. bellottii* reported by different authors.**Tab. 5: Pregled podatkov o obdobju drstitve za vrsti *P. careruleostictus* in *P. bellottii* po navedbah različnih avtorjev.**

Species	Authors	Area	Spawning period
<i>Pagrus caeruleostictus</i>	Navarro et al. (1943)	Mauritanian coasts	July - August
	Domain (1979)	Senegales coasts	April – May- August- September and December
	Dia et al. (2000b)	Nouakchott (Mauritania)	July – October
	Present study	Nouadhibou (Mauritania)	August – October
<i>Pagellus bellottii</i>	Ndiaye (2014)	Senegales coasts	January to June and August to November
	Present study	Nouadhibou (Mauritanie)	Females: July - December Males: August - November

**Fig. 3: Size at first sexual maturity in males (left) and in females (right) for *Pagrus caeruleostictus*.****Sl. 3: Velikost samcev (levo) in samic (desno) vrste *Pagrus caeruleostictus* ob spolni zrelosti.**

16 individuals of undetermined sex).

The GSI maturation stages in *Pagrus caeruleostictus* (Tab. 5 and Fig. 2) have been identified as follows:

- The pre-maturation period is from January to April for both sexes.
- The ripening period extends from May to June.
- Spawning and fertilisation takes place from August to October with a coincidental peak in August with release of male products but beginning slightly earlier, in late July.

In *Pagellus bellottii* (Tab. 5 and Fig. 2):

- The pre-maturation period lasts from May to June for females and from March to May for males.
- The maturation period occurs from May to August for males and from May to July for females.
- The spawning period is from July to December

with a peak in late July for females, and from August to November with a peak in late July and August for males.

We observed a one-month lag between the reproductive periods of males and females in *P. bellottii*; the release of sex products tends to occur in bursts, which makes this species a batch spawner.

Size at first sexual maturity

Size at first sexual maturity is taken as the length at which 50% of individuals are mature. Maturity is reached by all those individuals whose gonads are at their maximum development and occupy the entire abdominal cavity, corresponding to stages 3 and 4 of Mann and Buxton's scale (1998).

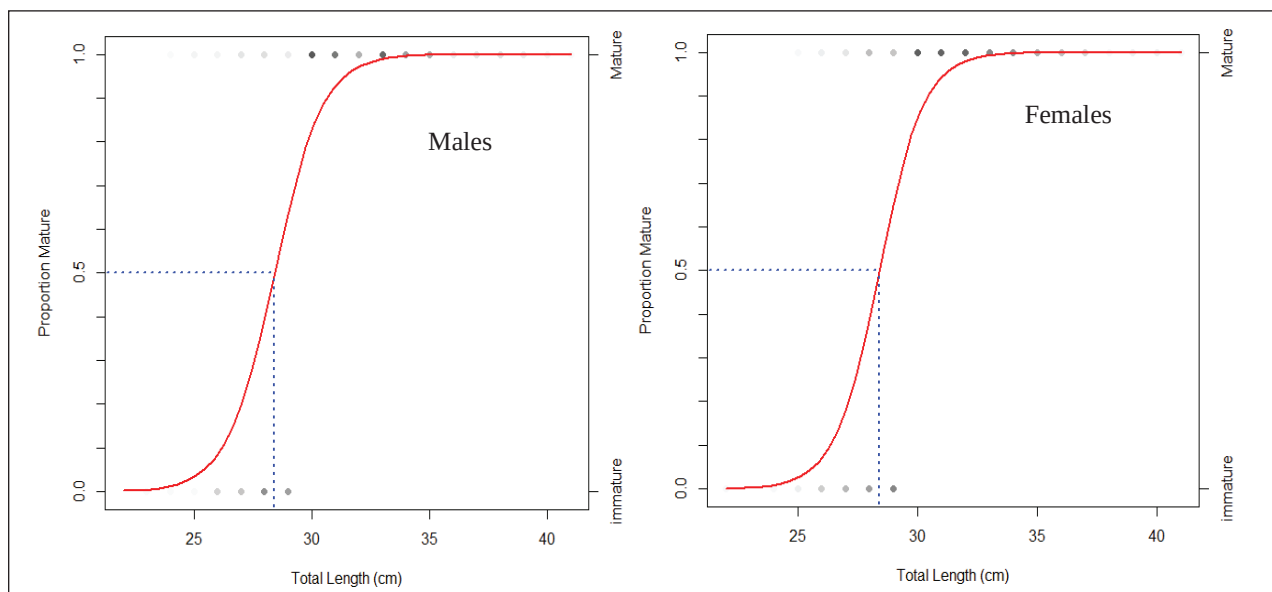


Fig. 4: Size at first sexual maturity in females (left) and males (right) for *Pagellus bellottii*.
Sl. 4: Velikost samcev (levo) in samic (desno) vrste *Pagellus bellottii* ob spolni zrelosti.

According to generalised linear model results, the length at first sexual maturity (L50) in *P. caeruleostictus* is reached at 28.4 cm in males and 28.6 cm in females, whereas in *P. bellottii* it is reached at 20.04 cm in males and 19.6 cm in females (Figs. 3, 4). The smallest mature male individual in our samples of *Pagrus caeruleostictus* measured 24 cm fork length, the smallest mature female 25 cm. The smallest mature individual in *Pagellus bellottii* was 18 cm in males and 17 cm in females.

Tab. 6: Summary of the parameters of the Von Bertalanffy equation relating to the linear growth of *Pagrus caeruleostictus* and *Pagellus bellottii* from the Mauritanian coast. (FL = fork length; K = growth curvature parameter; t_0 = theoretical age of fish at zero total length).

Tab. 6: Pregled parametrov von Bertalanffyjeve enačbe glede linearne rasti pri vrstah *Pagrus caeruleostictus* in *Pagellus bellottii* iz mavretanske obale (FL = dolžina do vilice; K = parameter rastne krivulje; t_0 = teoretična starost pri dolžini 0).

Species	Parameters VB			
	Sex	FL ∞ (cm)	K	t_0
<i>Pagrus caeruleostictus</i>	Males	48.60	0.10	0.23
	Females	47.90	0.16	0.80
<i>Pagellus bellottii</i>	Males	28.00	0.56	0.70
	Females	30.00	4.00	0.50

The large size at first sexual maturity in the two observed sparid species is explained by the fact that the samples were purchased at the artisanal port of Nouadhibou and small individuals are not targeted by commercial fishing.

Growth

Most fish living in temperate waters have seasonal variations in growth related to temperature, feeding, and reproduction (Pajuelo & Lorenzo, 2001; Ndiaye, 2014). The dynamics of the fish population cannot be understood without knowing the growth parameters. Size frequency and sex data for each species examined in this study were entered separately into the R software and used in the "TropFishR" package. The results obtained are shown in Table 6. The results on the growth parameters of both species are slightly different from those by other authors (Tab.7) due to the different methods used and geographical areas covered (Chakroun-Marzouk, 1985).

DISCUSSION AND CONCLUSIONS

According to the results of this study, the *Pagrus caeruleostictus* species does not display any significant difference in proportions of males and females, while in *P. bellottii* the difference is relevant (Tab. 3–4, Fig. 5). Analysis of the spawning period (release of sex product) in *P. caeruleostictus* was carried out from August to October for males and females. The spawning period is shorter in the northern zone than

Tab. 7: Main results on the growth parameters of the two species following different authors.**Tab. 7: Rastni parametri za obe vrsti po navedbah različnih avtorjev.**

Species	Authors	Area	Methods	FL ∞ (cm)	K	to
<i>Pagrus caeruleostictus</i>	Chakroun- (1985)	Tunisia	Scalimetry	54 .79	0.20	-0.14
	Dia et al. (2000b)	Nouakchott (Mauritania)	Scalimetry	41.19	0.24	-0.74
	Present study	Nouadhibou	Size frequency analysis with R	47.90	0.16	-0.80
<i>Pagellus bellottii</i>	(Mauritania)	Mauritanian coast	Nonlinear adaptation of Maquardt	♀ = 29.7 ♂ = 28.66	0.32 0.28	-0.039 -0.11
	Present study (2020)	Nouadhibou (RIM)	Size frequency analysis with R	♀ = 30 ♂ = 28	4.00 0.56	-0 .5 -0.7

in the southern zone of the Mauritanian exclusive economic zone (July to October) (Dia et al., 2000b, 2001). In *P. bellottii*, the release of sex products occurs from July to December for females and from August to November for males, with one-month lag between the two sexes.

The length at first sexual maturity in *P. caeruleostictus* was 28.4 cm in males and 28.6 cm in females (Tab. 6–7, Fig. 5). In *P. bellottii*, this size is 20.04 cm in males and 19.6 cm in females. The findings on the growth parameters of *P. caeruleostictus* and *P. bellottii* obtained through the method of size frequency analysis using R software, in which the Von Bertalanffy equation relating to growth was incorporated, show an asymptotic length greater in the north zone ($L_{\infty} = 48$ cm) than in the south area ($L_{\infty} = 41.19$) for *P. caeruleostictus*. A comparison of the populations of *P. caeruleostictus* in the north and south zones indicates better growth of the species in the north zone, which could be explained by the abundance of food in the marine protected area of the Banc d'Arguin (Fig. 1). The temperatures (between 18 and 22°C) of surface and coastal water masses in the study area varied according to the intensity of upwelling during the summer period (Gandega et al., 2016).

The length at first capture proposed by Decree 2015-159 implementing Law No. 017-2015 of 29 July 2015 relating to the Fisheries Code is 23 cm for *P. caeruleostictus* and 19 cm for *Pagellus bellottii*. The results of the present study set the size at first sexual maturity at 28 cm for *P. caeruleostictus* and 20 cm for *P. bellottii*.

Scientific campaigns of the Mauritanian Institute of Oceanography and Fishery (IMROP) have called attention to significant changes in the specific composition of demersal fish catches that have taken

place over the last decade. Indeed, noble species such as *Pagrus caeruleostictus* and *Pagellus bellottii* are still present in the captures, but their biomass and sizes of individuals caught have considerably decreased. Stock assessments of these two species have detected overexploitation in the northwest African sub-region since the early 2000s (Barry et al., 2003 and 2004). The results of the FAO working group also indicate that the impact of current fishing efforts on the species is far greater than that which would ensure an optimal long-term yield (FAO, 2006).

The main threat for *P. caeruleostictus* and *P. bellottii* remains demersal fishery, which exclusively targets these very species. But other types of fishing are also contributing to the decline of these species through so-called incidental or "accidental" capture (Belhabib et al., 2012). This is particularly the case for all cephalopod and shrimp trawlers that operate in the marine waters of West Africa, where almost 90% of their accidental catch is made up of these demersal species (Diop et al., 2004).

The biological cycles of the two studied species indicate a single spawning period, which results in a low reproductive potential and a reduced capacity to increase their populations (Pavlidis & Mylonas, 2011). These biological characteristics limit their resilience and their ability to recover from the phenomenon of continuous overexploitation.

However, no specific conservation measure has yet been undertaken in Mauritania to protect these species, apart from indirect conservation measures such as the creation of marine protected areas within their area of distribution, and octopus biological stops, which mainly target the recruitment period and breeding ground for octopus species.

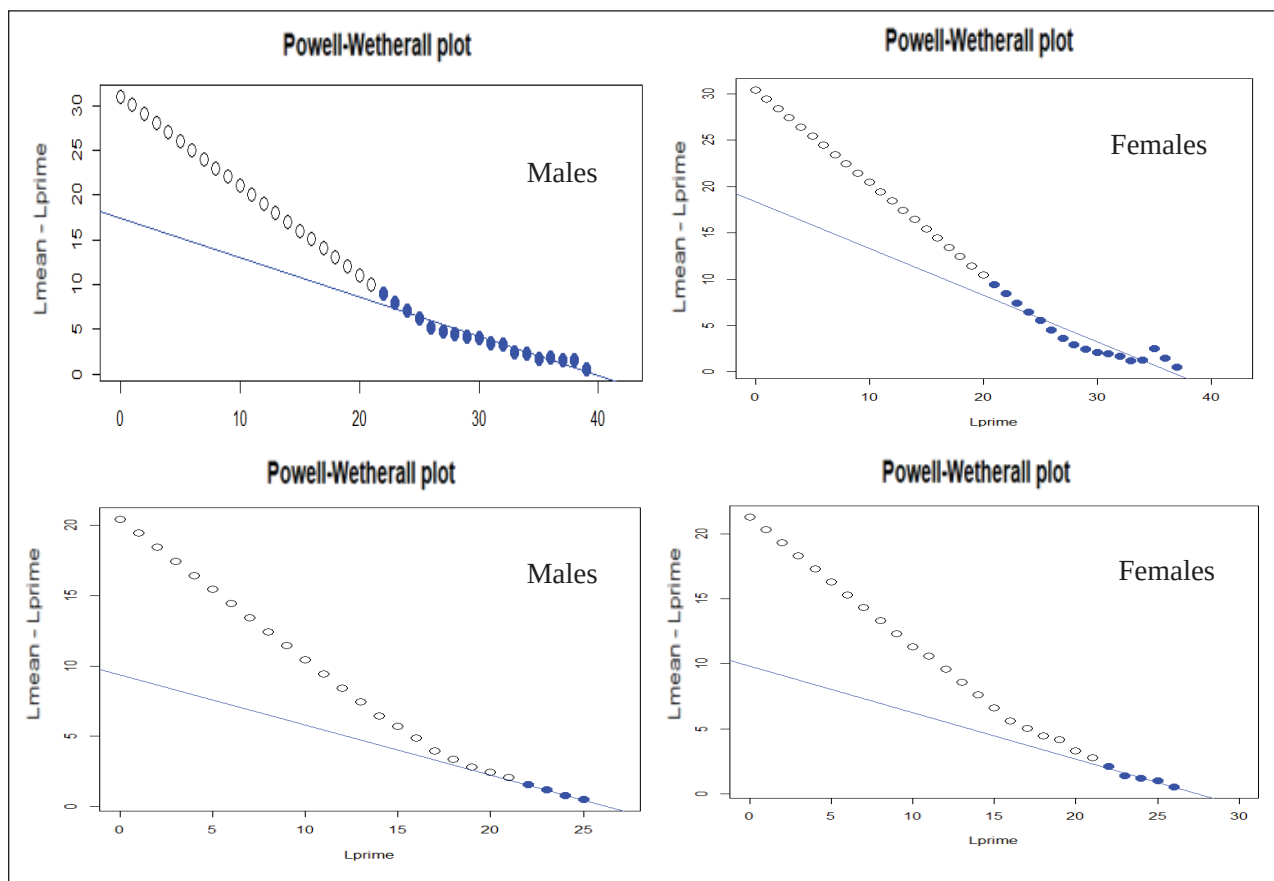


Fig. 5: Estimated mean lengths of *Pagrus caeruleostictus* (top) and *Pagellus bellottii* (bottom).
Sl. 5: Ocenjena povprečna dolžina primerkov za vrsti *Pagrus caeruleostictus* (zgoraj) in *Pagellus bellottii* (spodaj).

Still, even indirect conservative measures represent important protection of the various demersal fish. We strongly recommend their implementation and taking into account the reproduction periods of the two studied species as they have an important commercial value and there should be interest in better managing and preserving demersal resources. In fact, fishery resources are of

vital socio-economic interest for the Mauritanian community. The catch is often sold locally for fresh consumption, contributing to the protein balance of many inhabitants, or otherwise processed, frozen, and exported. Hence, fish are nutritionally and commercially important so stocks need to be managed rationally to ensure their sustainability and prevent overexploitation.

RAST IN RAZMNOŽEVANJE DVEH VRST PAGROV, *PAGRUS CAERULEOSTICTUS* IN *PAGELLUS BELLOTTII* V SEVERNIH MAVRETANSKIH VODAH (VZHODNI TROPSKI ATLANTIK)

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POVZETEK

Avtorji poročajo o parametrih rasti in razmnoževanja za dve vrste iz družine šparov (*Sparidae*) iz severne Mavretanije v 2020. Analizirali so 450 primerkov vrste *Pagrus caeruleostictus* in 516 primerkov vrste *Pagellus bellottii*. Odnos med spoloma je bil (samci: samice) 52,1% - 47,9% pri vrsti *P. caeruleostictus* in 53,2% - 46,8% pri vrsti *P. bellottii*. Spolne celice so opazili od avgusta do oktobra pri vrsti *P. caeruleostictus*. Drstitev vrste *P. bellottii* je potekala od julija do decembra pri samicah in od avgusta do novembra pri samcih, pri čemer je bil časovni zamik med spoloma en mesec. Dolžina samcev vrste *P. caeruleostictus* ob spolni zrelosti je bila 28,4 cm dolžina samic pa 28,6 cm. Pri vrsti *P. bellottii* je bila dolžina samcev ob zrelosti 20,04 cm, dolžina samic pa 19,6 cm.

Ključne besede: *Pagrus caeruleostictus*, *Pagellus bellottii*, rast, razmnoževanje, Mavretanija

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