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Pink Lobster, *Palinurus mauritanicus* (Gruvel, 1911), from the Mauritanian Coast: Elements of Biology and Exploitation

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ABSTRACT

Due to its biological characteristics (i.e. late sexual maturity, long reproductive cycle and high mortality of the larval phases due to predation and/or climatic hazards), the lobster is considered a highly vulnerable species. Furthermore, its high market value is such has led to a rush to exploit it to such an extent that some coastal cephalopods fishing vessels are being transformed into lobster vessels and European chartered vessels are arriving in Mauritanian waters. Therefore, in order to make the exploitation of this species biologically, economically and socially sustainable, a monitoring of landings of this species were undertaken from 2015 to 2018. From February 2015 to June 2018, on a regular basis and at each landing of vessels targeting pink lobster, (*Palinurus mauritanicus*), several times a week or even daily, sampling was carried out on board the vessels or at lobster production plants of this species at the time of their sorting and packaging. A total of 31770 individuals were measured and weighed; their level of maturity and moulting state were noted. This deep-sea species, reproduces all year round with a period of intense reproduction between August and December. The size of the smallest mature female mature female encountered during this period of experimentation (February 2015 to June 2018) is 213.5 mm TL. Moulting individuals appear from June onwards. The asymptotic length (CL_∞) of linear growth of Von Bertalanffy is 237.8 mm. The state of exploitation was studied using the Bayesian length-based biomass (LBB) estimator and indicates overexploitation of the pink lobster stock.

INTRODUCTION

In Mauritania, *Palinurus mauritanicus* to which Breton fishermen have gave the name of pink lobster, because of its pinkish hue after cooking (Forest and Postel, 1964) and also called Mauritanian lobster, constitutes with the green lobster, *Panulirus regius* the only species of the Palinuridae family occurring in Mauritanian waters.

The pink lobster, *Palinurus mauritanicus*, is found from the western of Ireland to the south of Senegal and in the western Mediterranean Sea to western Sicily, but not in the Adriatic (Holthuis, 1991), but also off the coasts of Spain, Portugal, Morocco, Algeria, Tunisia and Corsica. In the past, it was only fished commercially off Mauritania and the Sahara (Maigret, 1978). However, currently, it is also subject to targeted fishing in Algeria (Bouiadjraa et al., 2014; Benabdellah et al., 2016). In Mauritania, this species is encountered from north (20°40 N) to south (16° 05 N) and is found in the southern part of its range (Diop and Kojemiane, 1990). The scientific campaigns of the Institut Mauritanien de Recherches Océanographiques et des Pêches (IMROP) have noted the presence of this species between 20°34 N and 17°15 N at depths between 200 and 400 m.

According to Postel (1966), *P. mauritanicus* lives on the bottom near rocky areas and reef less coral formations on the edge of the continental shelf, particularly in canyons. In Mauritania this species is mainly found in a few pits on the continental shelf (Maigret, 1978) between 50 and 600 m with greatest abundance at depths between 80 and 200 m. However, it appears that this distribution follows the impact of trawling, which completely eliminated the species from the continental shelf where it was reported 25 to 35 years ago (Diop and Kojemiane, 1990). The absence of larvae of this species in the plankton after the breeding period led Maigret in 1978 to suggest that the larval stages (phyllosomes) are found off the continental shelf and would develop near the bottom, especially since fishermen have observed larvae of this species hanging on their fishing pots. The phyllosome larva of *P. mauritanicus* hatches at a very advanced stage compared to other palinurid larvae, which means that it remains in the plankton for a short period of time (Palero and Abelló, 2007). This first phyllosomal larva of *P. mauritanicus* is

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distinguished from other larvae of species of the genus by the early presence of periopods 4 and 5 in the form of small buds and by the long unfixed exopod of periopod 3 (Palero and Abelló, 2007).

It is a species living in cold waters with temperatures between 12 and 15°C and salinity varying from 35.5 to 36 ‰ (Diop and Kojemiane, 1990). *P. mauritanicus* is an omnivorous species, feeding on several types of animals living in the same biotope. Its trophic spectrum consists of polychaete annelids, bivalve molluscs, gastropods and cephalopods, crustaceans, echinoderms (ophinurids and echinids), eggs and fish. It would seem that this necrophagous species, which is a scavenging species, is more likely to feed on dead fish (Maigret, 1978).

In Mauritania, fishing for this species was initiated by fishers from the area of Camaret (France) around 1956, following the decline of the green lobster fishery (Maigret, 1978), which until then had been the main target species of French, Spanish and Portuguese fishers.

Available knowledge on this species is scattered in a series of old and poorly known documents that have never been revised (Goñi and Latrouite, 2005). Recently, many authors have been interested in the biology and ecology of this species through the larval phases, the phylogenetic link with other species of the genus and its fishery. We can cite Guerao *et al*. (2006) in the western Mediterranean, Palero and Abelló (2007) in Moroccan waters, Palero *et al*. (2009) in Morocco, Goñi and Latrouite (2005) in European waters. In Mauritania, in addition to the former rare works by Postel (1964), Maigret (1978), Boitard (1981) and Diop and Kojemiane (1990), recently two studies have been carried out by Kane *et al*. (2019) on Total Allowable Catches (TACs) and Sow *et al*. (2019) on its growth patterns and exploitation.

Due to its eco-biological characteristics, such as low growth rate, long lifespan, low fecundity, late sexual maturity, high mortality of the larval phases due to predation and/or climatic hazards, the pink lobster, similar to other species of the same genus, is very vulnerable to overexploitation (Goñi and Latrouite, 2005). In addition, its high market value is such that its exploitation has rapidly intensified and reached a state of overexploitation. Thus, the pink lobster fishery went through three phases between 1963 and 1988 (Diop and Kojemiane, 1990). One phase of overexploitation between 1963 and 1970-1971, a recovery phase between 1971 and 1987 and a second phase of overexploitation between 1987 and 1988. This second phase of overexploitation was the result of an intensification of fishing effort through the number of vessels increasing from 10 to 25 vessels following fishing agreements with the European Union (EU). Initially carried out by traps and then by gillnets introduced by the Portuguese, fishing for pink lobster is currently carried out using only gillnets.

In 2006, an improvement in the state of the stock (abundance index) was noted during the IMROP assessment campaigns. Despite this improvement, this species was not exploited again since 1988 until 2013, and only two targeting lobsters were supposed to be active in the area.

From that date, and more precisely in November 2013, a targeted fishery developed for this species and was noted by some operators through the transformation of some coastal cephalopod traps into lobster traps and the arrival of chartered vessels in the area.

In order to ensure the sustainability of this resource, to control the development of this fishery and to fill the information gaps related to this resource we have established, since 2015, a landings monitoring program for this species, conducted observations at sea and carried out work in the laboratory. The results presented here are those of the follow-up from 2015 to 2018.

MATERIALS AND METHODS

Fishing for pink lobster, initially carried out by traps and then by gillnets introduced by the Portuguese, is currently carried out using gillnets alone, and all landings are made in Nouadhibou, Mauritania, either at the Port Establishment of the "Baie de Repos" (EPBR) or at the Autonomous Port of Nouadhibou (PAN).

Between 2015 and 2018, on a regular basis and at each landing of vessels targeting pink lobster (several times a week or even daily), sampling was carried out on board the vessels or at processing and packaging plants for this species (Table I). Thus, a total of 31770 pink lobsters were sampled for biological information.

For each, we measured: the total length (TL) taken from the inter-orbital spine to the tip of the telson with the animal resting on a table and the length of the cephalothorax length (CL) taken from the tip of the rostrum to the posterior edge of the cephalothorax, both to the nearest millimeter. We weighed all these measured individuals to the nearest gram and noted the sex and level of maturity of female according to the maturity scale of Weinborn (1977) modified by Briones-Fourzna et al. (1981) (*in* Velazquez, 2005) (Table II). In addition, all moulting individuals were recorded.

In 2015, two grainy females were brought back to the laboratory for a fertility study. For that, the clustered eggs attached to the bristles of the endopodites of the pleopod (Fig. 1) and the associated pleopods were cut with a chisel and preserved in 5% formalin.

For growth studies, the ElefanI method under

Fisat II was used to estimate the parameters of the Von Bertalanffy growth equation CL∞ and K from monthly length frequency distributions (CL). The parameter t_0, it was calculated from Von Bertalanffy's inverse equation (Sparre and Venema 1996): $t - t_0 = [\ln(CL\infty) - \ln(CL\infty - CL)]/K$ or $t_0 = t - 1/K \times \ln(CL\infty - CL / CL\infty)$.

Table I. Total monthly population of pink lobster sampled between 2015 and 2018.

Months	2015	2016	2017	2018	Total
January	0	1097	1074	901	3072
February	742	475	1298	610	3125
March	341	990	1232	813	3376
April	2898	686	1010	355	4949
May	3547	1005	845	348	5745
June	2144	697	645	362	3848
July	950	0	0	0	950
August	1386	0	0	0	1386
September	0	0	0	0	0
October	0	0	0	0	0
November	1518	0	0	583	2101
December	1570	825	0	823	3218
Total	15096	5775	6104	4795	31770

Table II. Maturity scale of Panulirus inflatus proposed by Weinborn (1977) modified by Briones-Fourzna et al. (1981) (*in* Velazquez, 2005).

Sex stage	Characteristics
I	Without spermatophore or external incubating eggs
II	with spermatophore, without external incubating eggs
III	With light orange incubating external eggs
IV	With dark orange external incubating eggs
V	External eggs oculate coffee-coloured eggs
VI	Coffee-colored oiled eggs with remains of spermatophores and eggs or fine hairs to which the eggs adhere

For the analysis of the state of the resource, we used several indicators obtained through the monitoring of the fishery. The catch data were obtained through the logbook and recorded as tonnes per day of fishing. Data from on-board observers are also used in this experimental fishery to confirm data reported in the logbooks. The Bayesian length-based biomass (LBB) estimator (Froese et al., 2016), which is used for species that grow in size throughout their lives, as is the case for most fish and marine invertebrates. The Bayesian approach makes it possible to integrate a priori knowledge on the initial parameters of the model. Thus the L∞ obtained by the Elefan I method was used to fit the LBB model. To minimize the parameter requirements for LBB, the analytic framework is not based on absolute rates of growth and mortality, but rather on natural mortality rate (M) relative to somatic growth rate (M/K) and fishing mortality rate (F) relative to somatic growth rate (F/K), with the goal of estimating mean relative fishing mortality (F/M) and current biomass relative to unfished biomass (B/B0) (Froese et al., 2016), the LBB is used to estimate depleted or currently exploited biomass relative to unexploited biomass (B/B0). These model also make it possible to estimate the length at first capture that would maximize the catch and the biomass for a given fishing effort (CLc_opt) as well as an indicator of the relative biomass capable of producing the maximum balanced yield (Bmsy/B0) (Froese et al., 2016). The length (CLc) where 50% of the individuals are retained by the gear, the length (CLopt) where the unexploited cohort would have maximum biomass. The length at first capture CLcopt that maximizes catch and biomass for a given fishing pressure and leads to CLopt as mean length in the catch (Froese *et al*., 2016). CLc_opt,, that is a target length for the start of fishing which results in yields and catch per unit effort that are practically identical with the maximum that can be achieved with a certain fishing mortality. Thus current stock status B/B0 can be estimated by LBB from a combination of standard fisheries equations (Beverton and Holt, 1957, 1966). Also, the length CLc-opt can be calculated, which determines the CLc value that would result in CLopt becoming the mean length in the catch, with the highest catch and biomass for the respective fishing mortality and a minimized impact on size structure (Froese *et al*., 2016).

RESULTS

Reproductive period

During our sampling period, berried females were encountered throughout the year, with a period of intense reproduction with the maximum number of individuals observed between August and December.

It should be noted that starting in 2016, certain management measures were put in place, including a biological shutdown (fishing closed season) of 6 months (July to December) per year, to reduce the exploitation of this very sensitive resource. As a result, from this period onwards, very few berried females (Fig. 1) were found in the samples. This was also the case after an exemption was granted to operators from 2018 for a one-off fishery between 15 November and 15 December and postponing opening of the fishery to 1 February.

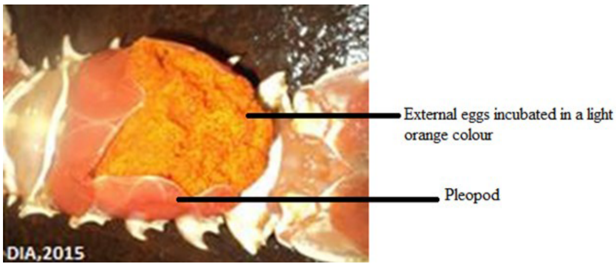

Fig. 1. Seeded female observed in 2015.

Size at first maturity

The size of the smallest mature female (stage 5) observed during our sampling period is 78 mm CL, and was recorded in March 2017. For the other years, this length was 80 mm in 2015 and 2016. Outside 2018 (CL of 83 mm), these lengths are below the legal size limit in place in Mauritania which is 230 mm of TL or 83mm of CL.

Fecundity

In total two berried female lobsters at maturity stage "3", of 115 mm CL (305 mm TL) and 135 mm CL (357.1 mm TL), weighing 1125g and 1391g respectively, yielded 154,800 eggs for the first female and 467,500 eggs for the second female.

Sex-ratio

Of the 31770 lobsters sampled, there were 17799 females (56%) and 13971 males (44%).

Length ranges by sex

An analysis of sex variation with size was also carried out. It would appear that the fluctuation is clearly significant when analyzing sex variation with size (χ2obs> χ2théo; ddl =34; α = 5%).

In general, for individuals smaller than 132 mm CL, females are predominant (Table III and Fig. 2) with the percentage of females decreasing with size. Thus, for a size of 112 mm CL, females represented 72% of the population and this percentage decreased to 63% for sizes of 127 mm CL. Above 132 mm CL, the proportion of males becomes more important. For sizes above 192 mm CL, only males were recorded.

Age and growth

We estimated t0 from the length of the Puerulus phase, a small lobster appearing after the last metamorphosis and corresponding t_0 age 0 of the species. According to Maigret (1978) and Postel (1964), in Mauritania this size is 70 to 80 mm (75 mm on average) in total length (TL) for the male and 60 mm for the female, i.e. 30.13 mm CL for the male and 22.55 mm CL for the female, following the allometric relationships we established by sex (Dia *et al*., 2016) : CL =0.4149*TL-0.9905 for males (N = 294 and R^2 =0.977) and CL=0.3841*TL-0.4965 for females (N= 516 and R^2 = 0.952).

Table III. Gender variation according to the size.

Inter Lct (mm)	Lct (mm)	Females	Males	Total
60-64	62	3	2	5
65-69	67	26	24	50
70-74	72	132	110	242
75-79	77	309	259	568
80-84	82	987	1018	2005
85-89	87	1253	1360	2613
90-94	92	1709	1912	3621
95-99	97	1189	1122	2311
100-104	102	1880	1246	3126
105-109	107	1329	663	1992
110-114	112	2286	893	3179
115-119	117	1186	485	1671
120-124	122	1812	850	2662
125-129	127	831	485	1316
130-134	132	1229	822	2051
135-139	137	372	386	758
140-144	142	566	783	1349
145-149	147	181	330	511
150-154	152	241	535	776
155-159	157	58	164	222
160-164	162	88	243	331
165-169	167	31	73	104
170-174	172	56	93	149
175-179	177	10	25	35
180-184	182	26	41	67
185-189	187	4	11	15
190-194	192	5	14	19
195-199	197	0	5	5
200-204	202	0	5	5
205-209	207	0	1	1
210-214	212	0	6	6
220-224	217	0	3	3
225-229	222	0	1	1
230-234	227	0	1	1
Total		17799	13971	31770

Table IV. Monthly distribution of moulting lobsters by size.

Inter Lct	March	April	May	June	July	August	November	December	Total
65-69					1				1
70-74				1	1				2
75-79		1	10	3	1	5			20
80-84	8	3	66	30	13	15			135
85-89	5	9	75	68	22	12	1		192
90-94	14	14	45	90	23	41	4	1	232
95-99	2	5	21	65	5	4	3		105
100-104	4	3	11	38	7	31	5		99
105-109	1	5	2	14	7	2	4	2	37
110-114	1	9	9	9	13	18	2		61
115-119		3	1	3	5	2			14
120-124		7	6	3	15	21			52
125-129	2	2	3	3	6	4	2	1	23
130-134		4	6	1	14	20		2	47
135-139		2	2		5	3			12
140-144		6	2		3	9	4		24
145-149		1		1	3	3			8
150-154			1		5	6	1	1	14
155-159		1	1						2
160-164		1	1	1	1	3	1		8
170-174						3		1	4
180-184						1			1
Total	37	76	262	330	150	203	27	8	1093

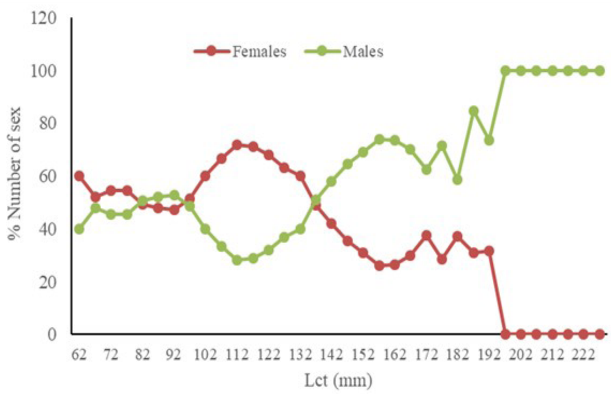

Fig. 2. Sex distribution according to size of pink spiny lobster.

The linear growth parameters are given in the Table IV.

Thus, Von Bertalanffy's linear growth equations for pink lobster, are of the form:

$CL\ (t) = 198.6*(1- e^{-0.22(t+0.55)})$ for the females of the pink lobster

$CL\ (t) = 237*(1- e^{-0.29(t+0.47)})$ for the males of the pink lobster

$CL\ (t) = 237.8*(1- e^{-0.21(t+0.56)})$ for both sexes

Moult

We considered as "moulting" any lobster whose teguments are either soft or broken, revealing a new cuticle (Fig. 3). Overall, the maximum number of moulting individuals observed was from June onwards. A total of 1,093 spiny lobsters were moulting out of all the individuals sampled (31770), comprising of 490 females and 603 males, with a non-significant difference. It should be noted that during this life stage, the highly vulnerable species does not have a high market value and many fishers release it back into the water as soon as they notice its moulting state, which would explain the low number of moulting specimens in the samples we collected and processed.

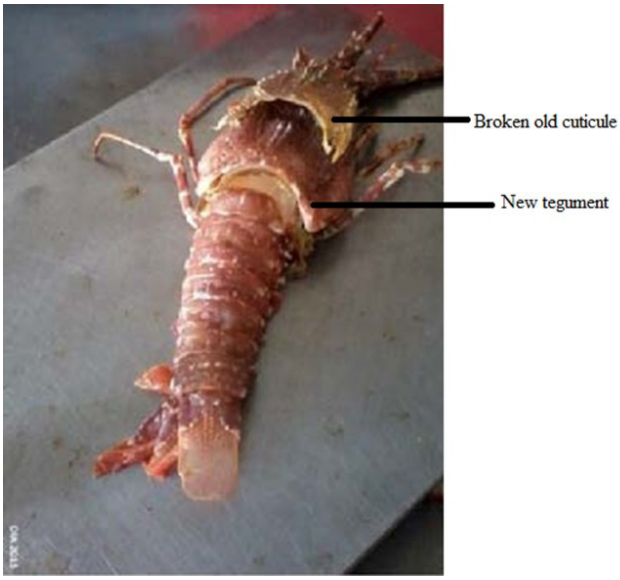

Fig. 3. Pink lobster male moulting in June 2015.

Description of the current fishery

At the beginning of the monitoring of the experimental fishery, the pink lobster fishery was carried out by coastal and offshore vessels using exclusively 180 mm stretched mesh, 25 to 40 m long and 2 m drop gillnets with 10 to 18 sets of 400 nets per vessel. At the end of the first monitoring year, on 22 February 2016, a development measure was introduced and set the maximum length of the net at 40 metres, the series at a maximum of 1600 meters with a number of nets not exceeding 800 nets.

The gear used in the pink lobster fishery resulted in significant bycatch dominated by various demersal fish followed by scorpion fish and crabs. Thus, for one kg of lobster caught, the by-catch varied from 1.04 to 14.5 kg.

At the beginning of the exploitation the bycatch of high value species (e.g. *Hyperoglyphs moselii*). As the value of these catches was below the tax imposed on one kilogram of bycatch, the shipowners resolved to discard all bycatch, despite the loss of income to the company.

Evolution of the nominal effort

At the start of pink lobster harvesting in 2015 (January to December), the authorized number of lobster vessels was 22 units between 14 and 26 m length and power rating between 150 and 500 hp (Table V). This number rose from 20 to 25 units from 2016 to 2017 before dropping significantly in 2018 to 14 vessels, following the withdrawal of the majority of chartered units.

Fishing effort

The rush for pink lobster, a species of high commercial value, resulted in a rapid increase in fishing effort in the first year of exploitation. Thus, the fishing effort reached 2575 days at sea in 2015 before gradually decreasing until 2018. In 2018, this effort was 1316 days at sea (Fig. 4).

Table V. Parameters of the Von Bertalanffy equation.

Methods	Females		Males		Females and males	
	Lc∞ (mm)	K (year -1)	Lc∞ (mm)	K (year -1)	Lc∞ (mm)	k (year -1)
Elefan I	198.6	0.22	237	0.29	237.8	0.21
t_0	-0.55		-0.47		-0.56	

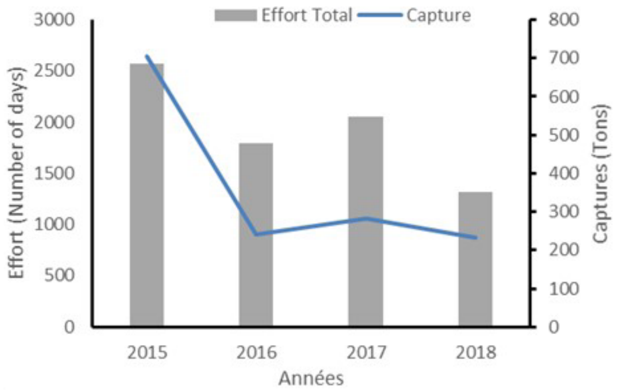

Fig. 4. Annual evolution of effort catches in the pink lobster fishery.

Trends in catches

Catches of Palinurus mauritanicus peak at more than 700 tonnes in 2015 and fall drastically in subsequent years. Between 2016 and 2018, annual catches were around 250 tonnes (Fig. 4).

Trends in catch per unit of effort (CPUE)

The intense exploitation of pink lobster between 2015 and 2016 has led to a significant and rapid decline in CPUE. The CPUE fell from 273 kg per day at sea in 2015 to 135 kg per day at sea in 2016, a reduction of 50% in one year. In the following two years, it increased slightly to around 180 kg per sea day in 2018 (Fig. 5). This recovery could be due to a decrease in the fishing pressure or total effort from 2575 fishing days in 2015 to 1316 fishing days in 2018.

Demographic structure of landings

Between 2015 and 2018, the monitoring program carried out by IMROP enabled 31770 measurements of pink lobsters to be taken. In 2015, the size structure indicates that about 75% of the individuals were between 90 and 140 mm CL with a mode at the level of size class 110-119 mm (Fig. 6). In the following years, there is a shift to the left of the population structure meaning that the fishery began to exploit smaller individuals. Modes are at the size classes of 90-99 mm. By 2018, the size classes (90 and 140 mm) account for only 66.6% of the total number of individuals.

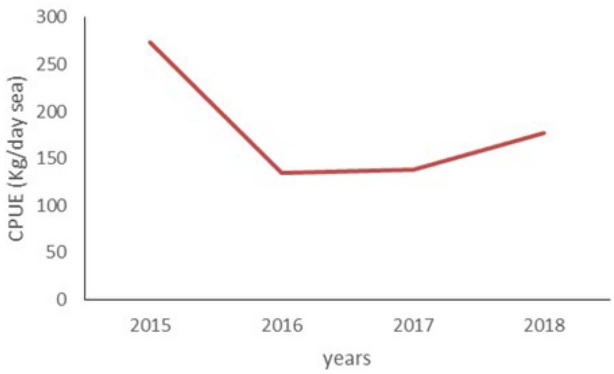

Fig. 5. Catch per unit effort of pink lobster.

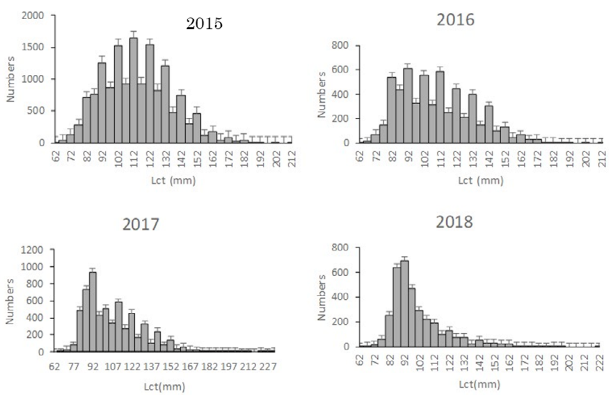

Fig. 6. Annual evolution of the demographic structure of the pink lobster landed in Nouadhibou between 2015 and 2018.

Annual evolution of the average length of the catches

The average lengths of pink lobsters observed in the catches are continuously decreasing. They went from their maximum level of 114 mm recorded in 2015 at the beginning of the experimental fishery to their minimum level of 100 mm in 2018. In 2017, this average size is 107.6 mm CL (Fig. 7).

Stock status of pink lobster

The assessment method based on size structures at landing allowed the determination of an optimal size (CLopt) of 160 mm and the first catch (CLc_opt) at 140 mm.

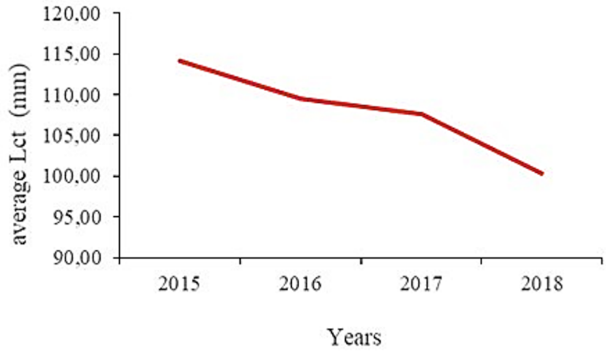

Fig. 7. Annual change in the average length of pink lobster landed between 2015 and 2018.

Table VI. Characteristics of the main vessels targeting pink lobster in 2015/ 2016.

	Characteristics	Number
c-c) Length (m)	≤14	3
	15-20	11
	20-26	11
Power (CV)	< 150	4
	150-285	5
	285-500	13
	≥ 500	3

With a size at first capture of CL = 83.5 mm, the average value of the asymptotic length (CL∞) is 227 mm. The lengths (CL∞) obtained during these four years are lower than the initial (prior) value of 237mm obtained by the Elefan method. The results obtained per year show a degraded situation in 2017 and 2018 compared to the years 2015 and 2016 with size structures dominated by smaller sizes of pink lobster.

The ratio of mean size to asymptotic size (CLmean/ CL∞ =0.69) indicates a mean size of exploited individuals below the optimal size. The resulting estimates of relative natural mortality to somatic growth K and relative fishing mortality to M for the age groups represented in the length frequency sample are M/K = 1.32 and F/M = 2.43 respectively.

The current exploited biomass relative to the unexploited biomass (B/B0= 0.17) indicates a strong reduction in relative biomass leading to a low yield per recruit (Y/R'= 0.025) of Beverton and Holt. Also, the current relative biomass obtained in relation to that capable of producing maximum sustainable yields (B/BMSY) is 0.45 (0.22-0.76). All of these exploitation indicators indicate a situation of overexploitation of pink lobster in Mauritania.

DISCUSSION

Biology

The period when grainy females are observed in the catches, with maximum intensity between August and December, is consistent with the results of many authors. Indeed, Maigret (1978) mentions that the pink lobster reproduces all year round with a maximum egg-laying period between August and January. It would seem that this period coincides with the end of the warm waters and the period when females concentrate in certain pools and may in some cases reach the level of the continental shelf up to 150 m deep.

Regardless of the size of the smallest seeded or egg-bearing female encountered during our monitoring period, it is smaller than the one encountered in 1978 by Maigret in Mauritanian waters, which was 250 mm TL. In 1981, the smallest seeded female observed by Boitard in our study area, was larger than ours and measured 90 mm CL, or 239.2 mm TL. In 1964, Postel reported that the smallest mature female pink lobster in the same area was 270 mm TL. The decrease in the size of the smallest female compared to that observed in 1978 and 1981, respectively, by Maigret and Boitard could be explained by a stock response to fishing pressure. It should be noted in passing that the pink lobster has undergone two phases of overexploitation. This decrease in size at maturity could also be a response to a change in environmental conditions (temperature) or the combined action of the two factors. Indeed, as mentioned by Goñi *et al*. (2003), factors such as food availability, population density or water temperature are known to influence growth rates and thus size at maturity.

It should be noted that we have rarely found spermatophores attached to the sternum of females and in the vicinity of the genital orifices. It is likely that most females, while struggling in the nets, lose their spermatophores.

The numbers of eggs we obtained with stage 3 females are 154,800 eggs for the smallest female and 467,500 eggs for the largest female. These numbers are higher than those obtained by Maigret in 1978 when counting eggs of this species in the same study area, for females between 34 and 38 cm Lt (average 60,000 eggs) while Diop and Kojemiakine (pers. comm. made to Goñi and Latroute, 2005) found a relative fecundity of 136,000 eggs per kg (n = 92). This difference in the number of eggs could be related to the incubation of eggs or the loss of these eggs during handling in the laboratory. In the case of green lobster, for the same size, the number of eggs varies according to the stage of maturity (Dia et al., 2015). It appears to be more important at the beginning of incubation (stage 3) than at a later stage of incubation (stage 4). Campillo and Amadei (1978) note the possibility of significant egg loss during incubation. Morgan (1972) estimates that this loss may be as high as 10% in *Palinurus longipes cygnus* for an incubation period of 3.5 to 8 weeks. This loss of eggs during incubation has been estimated at 10% by Mercer (1973) in Atlantic *P. elephas* and 26-28% by Marin (1985) and in Mediterranean *P. elephas* specimens. According to Goñi *et al*. (2003), the lower water temperature and the means of capture used in (hand fishing instead of netting) would explain the much lower rate of egg loss in the Atlantic study.

The absence of females at sizes greater than 19 cm Lct could be explained, as suggested by Marchal and Barro (1964), by the fact that males grow faster and that molts are more widely spaced in females because the presence of eggs prevents them from molting over long periods. Furthermore, Postel (1964) and Maigret (1978) showed that at equal age, already at the Puerulus stage, the male is larger than the female. Guerao *et al*. (2006) obtained, for the same Puerulus stage, in the western Mediterranean for both sexes combined, a TL between 23.3 and 24 mm or CL between 8.8 mm and 9 mm, much smaller than that observed in Mauritania. Maigret (1978) thought that the predominance of males in the larger sizes is related to their greater longevity. It seems that sex and size vary according to depth. Thus, males would be more abundant between 150 and 250 meters, while large females and immatures would predominate beyond 300 meters (Maigret (1978)).

Maigret (1978), estimated an increase in length after moulting of 30-40 mm after recapture of a few marked males with an initial size of 250-270 mm TL. Similarly Vincent-Cuaz (1966) estimated an increase in size after moulting of 30 mm. He thus divided sizes between 270-490 mm TL into 8 age groups (9-16 years) for males and females. Boitard (1981), referring to data from Maigret (1978), proposed the following growth parameters for females: = 202.8 mm, K = 0.169, at t_0 = 0.227

The best method for studying the linear growth of crustaceans is tagging (capture and recapture). However, the high market value of this species means that all attempts at tagging have so far failed due to the lack of cooperation from artisanal fishers. Nevertheless, the ElefanI method under Fisat II, which we used, gives the same length $CL\infty$ for females of 199 mm as that obtained by Sow et al. (2019) using the same method on an 8- to 9-month sample in the same study area. This length is close to that obtained by Boitard (1981) using the capture and recapture (tagging) method. Maigret (1978) estimated that *P. mauritanicus* could live for at least 21 years.

Although the maximum moulting lobster was observed in June, in the last 2 years (2017 and 2018), moulting lobsters have appeared a little earlier (March and April), probably due to environmental factors, with surface temperatures of 21.5°C in March and April above the seasonal norm of 19°. Indeed, according to Maigret (1978), who studied this species off the Mauritanian coast, males and females moult only once a year, between September, the warm season with a temperature of about 25°C (Dubrovin *et al*., 1991) and December, the warm-cold transition season with an average temperature of 20°C.

Stock status

The state of the stock obtained, through estimates of the relative biomass of LBB, reflects the level of decline of the pink lobster stock following its intense exploitation from 2015 onwards. The high level of fishing effort from the first year in 2015 led to the rapid overexploitation of this species, which had been in the same situation in the past in 1963 and 1988 (Josse, 1988). The catches obtained between 2015 and 2018 exceeded the level of exploitable potential obtained in 1988, which is, in fact, the last assessment producing exploitable potential on the basis of a biomass production model for which a series of at least ten years of data on the exploitation of this species is necessary in order to apply it.

The rapid decline of this resource and the slow recovery of the stock are elements that confirm the vulnerability of this species as for all species of the genus (Goñi and Latrouite, 2005).

The management strategy for this vulnerable resource, so far adopted by Mauritania in its Fisheries Code, relates to individual size or biological condition:

Minimum landing size of 23 cm in relation to the reproductive size

Release of grainy females in order to maintain a fertile biomass,

These measures relating to the individuals caught are necessary, but the fisheries regulated only by these types practically all declining because they do not prevent fishing effort and exploitation rates from becoming excessive (Latrouite and Lazure, 2005).

This is why, after the first year of monitoring, which made it possible to determine the period of intense reproductive activity and moulting, management measures for the fished population were put in place. These measures relate to the annual quantity of catches taken (TACs) and fishing effort.

The control of catches is based on:

Fleet: The authorised effort in the pink lobster fishery is capped at 14 vessels all flying the Mauritanian flag.

The TAC, which was 800 tonnes by decision of the Ministry at the beginning of the experiment, was reduced to 500 tonnes by decision of the supervisory authority following the first signs of overexploitation.

The control of fishing effort is based on:

Gear: The length of the net, the number of sets and the number of nets allowed per vessel.

Seasonal closure of fishing: Fishing is prohibited from June 30 to December 31 each year. In 2018, an exceptional one-month fishing opening was instituted.

These management measures are accompanied by technical measures prohibiting any by-catch of pink lobsters by vessels without a lobster license.

In order to better protect this resource, it would be beneficial to put in place management measures requiring vessels to hand over soft individuals, that is, individuals that have just moulted, and to use more selective fishing gear such as traps. In fact, during this experimental fishery, only gillnets were used due to their effectiveness, but in the past, traps were used and proved to be more sustainable. In South Africa Groeneveld (2000) showed that trawls and traps catch small sizes but traps tend to catch larger sizes that are more vulnerable.

CONCLUSIONS

Following the initial results (spawning and moulting period) of the continuous monitoring of the pink lobster fishery, which made it possible to gradually take management measures (introduction of a biological halt), the nominal fishing effort expressed in terms of number of vessels has fallen significantly. On the other hand, production has decreased enormously since the start of the fishery and this production has consisted mainly of small individuals over the last two years, leading to a considerable drop in the average length of landings. This indicates a deterioration in the stock situation of this resource. In fact, from more than 700 tons to less than 300 tons per fishing season, the production figures and monitoring results over these four years unequivocally indicate that, overexploited twice between 1963 and 1971 and between 1987 and 1988, the pink lobster stock currently exploited by the national fleets is in poor condition. This state of overexploitation could be related to the fishing technique in place, especially through the accumulation of lengths immersed by the fleets and the vulnerability of lobsters to the gears by which they are caught and/or to increasing fishing effort. A start could be made on restoring stocks to a level compatible with sustainable exploitation when the management measures put in place after the first years of monitoring are strictly adhered to. Other measures to increase the spawning or spawning biomass, particularly of females, could be envisaged by fixing the minimum catch size at that obtained by the LBB model, i.e. CLc-op of 140 mm.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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