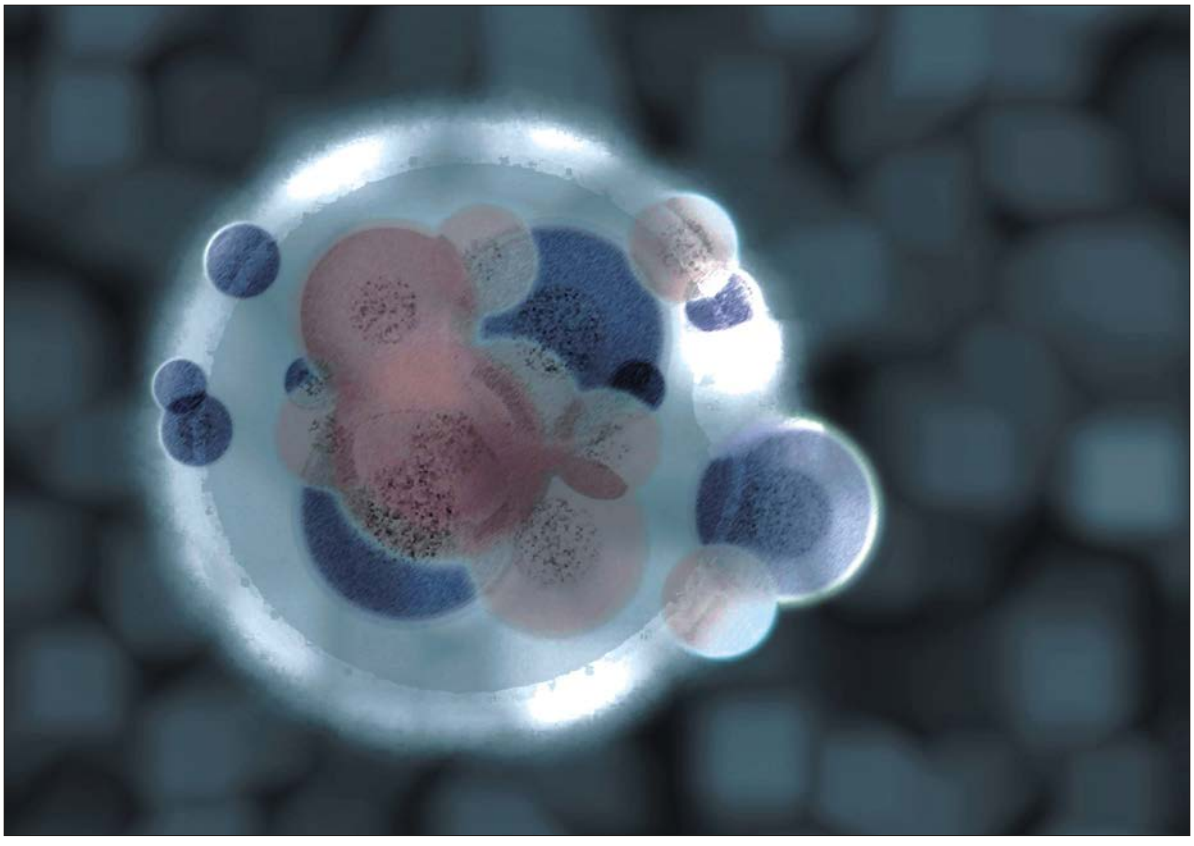

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Research Article
Variation of the Condition Index and Sex-ratio of the Sea Urchin *Paracentrotus lividus* in the Southeast Mediterranean

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Abstract

Objective: The objective of this study is to monitor the variation in the condition index at the level of two populations, male and female of the sea urchin *Paracentrotus lividus* (Lamarck, 1816) fished in the most Southeastern part of the Mediterranean (Gulf of Annaba) and the structure of the population through sex-ratio determination. **Methodology:** Sampling was done monthly from February, 2012 to January, 2013 at three stations (Gap de Garde, Lacaroube and Draouch) and the physico-chemical characterization of the water was performed by *in situ* measurements of temperature, pH, salinity and dissolved oxygen. In addition, the individuals harvested were dissected, sexed and weighed to determine their condition index and the sex-ratio. **Results:** The physico-chemical parameters revealed that the waters of the 3 sampling stations are favorable for the development of the sea urchin *Paracentrotus lividus*. Furthermore, the condition index indicated that the highest values were recorded in spring (March and April). However, the lowest values were found between July and November. **Conclusion:** Overall, the structure of the population of *Paracentrotus lividus* differed from one station to another, the sex-ratio of the population was estimated at 46.99% at station S1, 39.11% at station S2 and 48.31% at station S3.

Key words: *Paracentrotus lividus*, sex-ratio, condition index, males, females, gonads, temperature, gonadal maturation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In the Mediterranean, the sea urchin *Paracentrotus lividus* (Lamarck, 1816) is one of the benthic invertebrate species subject to the most pressure for commercial and recreational purposes[1]. This sea urchin has a broad distribution throughout the Mediterranean sea[2,3], ranging from the upper mediolittoral to infralittoral zones to a depth of less than 80 m[4,5]. It exhibits close linkages with the substrate, derived from their life habits such as locomotion and feeding[6]. Its population density presumably expresses negative feedback by modulating growth and reproduction[7]. Due to its sedentary habits and sensitivity to pollutants, it has been used in several studies as an indicator of local biological and biochemical pollution[8]. Its responses to environmental conditions are considered to be changes in its physiological processes linked to its phenotypic plasticity[9-11]. In addition, its gonads are considered a delicacy[12] and have made it one of the most popular sea foods in different countries[13,14]. The Mediterranean sea urchin *Paracentrotus lividus* has been the subject of numerous studies[11,15-19]. However, regarding Algeria only the Southwest part of the coast has been studied with respect to the sea-urchin *Paracentrotus lividus*, with studies from Dermeche *et al.*[20], Soualili and Guillou[21] and Guettaf *et al.*[22]. As a result, this study focused on the biology of the sea urchin *Paracentrotus lividus* inhabiting the extreme Southeast Mediterranean (Gulf of Annaba) by monitoring the monthly variation in the condition index of both male and female populations determining its sex-ratio.

MATERIALS AND METHODS

The study was conducted from February, 2012 to January, 2013 in the Gulf of Annaba (Fig. 1). The latter is limited on the East by Cape Rosa and on the West by Cap de Garde[23]. Three sampling stations were chosen, the characteristics of each of these stations are given in Table 1.

It was characterized the environment by *in situ* measurements of the physicochemical parameters of the water (Temperature, pH, salinity and dissolved oxygen), using a multi-parameter measurement system. Thirty sea urchins were harvested and transported to the laboratory in coolers filled with oxygenated seawater. The samples were dissected and weighed using a caliper and a balance. Sex determination was based on the color of the gonads, the testicles are a creamy-yellow color and the ovaries orange. Sometimes the color of the gonads can be very light or very dark, making it impossible to determine the sex, thus the sex of the individuals concerned is considered indeterminate. The physiological state of the organism was determined by calculating the Condition Index (CI) proposed by AFNOR[24]:

$$\text{Condition Index (CI)} = \frac{\text{Weight of mass mole}}{\text{Wet weight total}} \times 100$$

Sex was determined by observation of the color of the gonads and their milt[15]. Population structure was determined by calculating the ratio suggested by Loubens[25]:

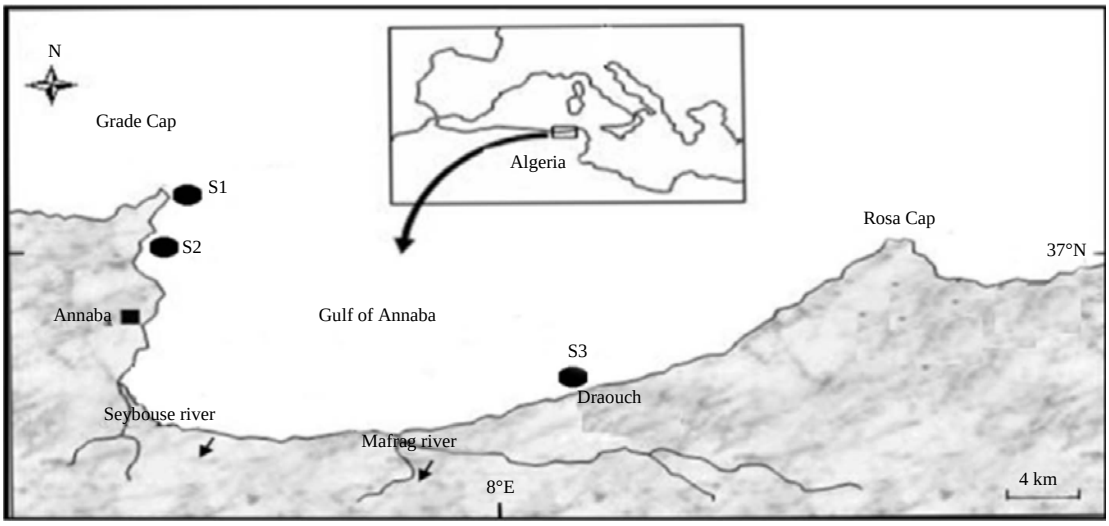

Fig. 1: Representation of the sampling stations in the Southeast Mediterranean (Gulf of Annaba, Algeria)

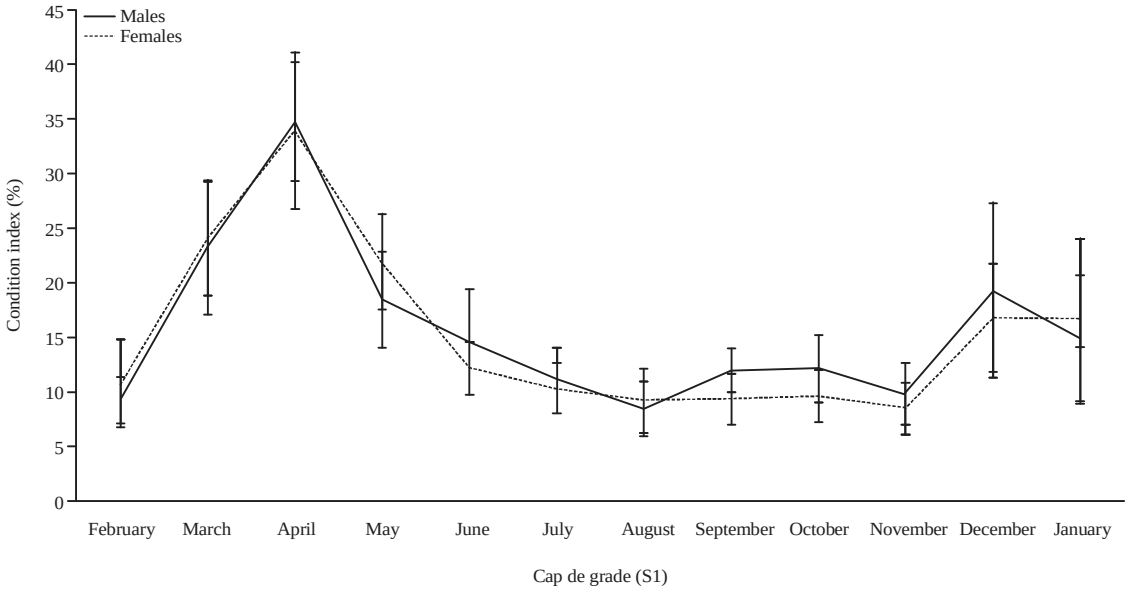

Fig. 2: Temporal variation in the condition index at station 1 (Gulf of Annaba, February, 2012-January, 2013)

Table 1: Characterization of the sampling stations of the Gulf of Annaba (Algeria)

Position of sampling stations	Geographic coordinates	Soil
Cap de Grade (S1)	36°58' 04.03"N	Rocky
	07°47' 29.81"E	
Lacaroub beach (S2)	36°56' 00. 95"N	Sandy
	07°45' 57.59"E	
Draouch beach (S3)	36°52' 30.62"N	Sandy
	08°02' 56.77"E	

$$\text{Sex-ratio} = \frac{\text{No. of males}}{\text{No. of males+No. of females}} \times 100$$

Statistical analysis: The data are expressed as average values±standard errors and the statistical analysis of the data was performed using the Minitab 13 software. The variation of the condition index between the two sexes was assessed by the Student test. Also, the hypothesis null H_0: Sex-ratio = 50% was verified by the chi-square test (χ^2) to indicate the proportion of each sex. Corrections between sets of parameters (CI of males, CI of females, temperature, salinity and dissolved oxygen) were evaluated to analyze the intensity of relations between parameters.

RESULTS

The results of the monthly variation of physico-chemical parameters are presented in Table 2. The average values of the physico-chemical parameters of the water are between 14.17 and 29.43°C for temperature, 9.36 and 8.03 for pH, 37.23 and 31.63‰ for salinity, 0 and 011.11 mg L^{-1} for dissolved oxygen. It appears that the highest values were recorded at summer temperatures, the pH was slightly alkaline and the dissolved oxygen content over the base (0 mg L^{-1}) is indicated for the summers of 2012 and 2013 for the 3 sampling stations.

The monthly evolution of the condition index revealed a similar trend for both sexes at the three stations, while the Student test showed no significant difference between the sexes for station S1 (T = 0.12, p = 0.90), station S2 (T = -0.50, p = 0.96) or station S3 (T = -0.93, p = 0.36). At the level of station S1 (Cape de Garde) a peak was reported in April for both male and female populations with values in the range of 34.92±5.4 and 34.12±7.18, respectively (Fig. 2). However, this index fell during August for males (8.61±2.49%) and during November for females (8.55±2.41%).

Regarding station S2 (Lacaroub), the highest CI values were found in March (27.37±8.34%) for the male population and in April (28.01±5.27%) for the female population (Fig. 3). The minimum was found in July (7.12±2.4%) and August (5.49±3.15%) for males and females, respectively. For station S3 (Draouch), the maximum condition index was recorded in

Table 2: Annual variation of water physicochemical parameters in sampling stations (Gulf of Annaba; February, 2012-January, 2013)

Months	Stations	pH	T	S	DO
February	S1	9.01	13.90	35.35	2.06
	S2	9.21	14.17	35.94	2.68
	S3	9.36	17.87	35.83	11.11
March	S1	9.23	14.90	34.17	2.50
	S2	9.13	16.03	31.63	3.50
	S3	8.44	18.87	34.23	1.57
April	S1	9.08	16.83	35.67	9.47
	S2	8.90	17.67	35.30	3.01
	S3	8.49	18.87	35.37	10.13
May	S1	8.81	18.93	35.50	1.46
	S2	8.84	19.93	35.60	1.46
	S3	8.61	22.97	35.40	4.86
June	S1	8.62	23.30	35.97	3.22
	S2	8.13	22.87	34.93	0.00
	S3	8.85	29.43	35.30	6.89
July	S1	8.38	26.67	37.23	4.50
	S2	8.03	26.04	35.77	0.00
	S3	8.14	28.23	35.27	2.70
August	S1	8.40	25.63	36.30	0.32
	S2	8.52	26.60	32.80	0.00
	S3	8.85	27.87	35.83	3.35
September	S1	8.35	25.37	36.30	4.35
	S2	8.40	24.93	36.50	3.54
	S3	8.41	24.03	36.23	4.35
October	S1	8.36	25.63	36.27	5.14
	S2	8.63	27.40	36.27	1.83
	S3	8.46	22.10	35.43	2.06
November	S1	8.46	24.03	35.43	2.06
	S2	8.26	23.47	35.27	2.68
	S3	8.42	16.73	34.40	2.63
December	S1	8.56	8.56	34.83	6.97
	S2	8.56	8.56	34.50	8.30
	S3	8.73	15.00	33.90	7.75
January	S1	8.77	25.63	34.67	3.14
	S2	8.67	16.60	34.45	1.83
	S3	8.86	18.00	35.27	5.33

T: Temperature (°C), S: Salinity (‰), DO: Dissolved oxygen (mg L^{-1})

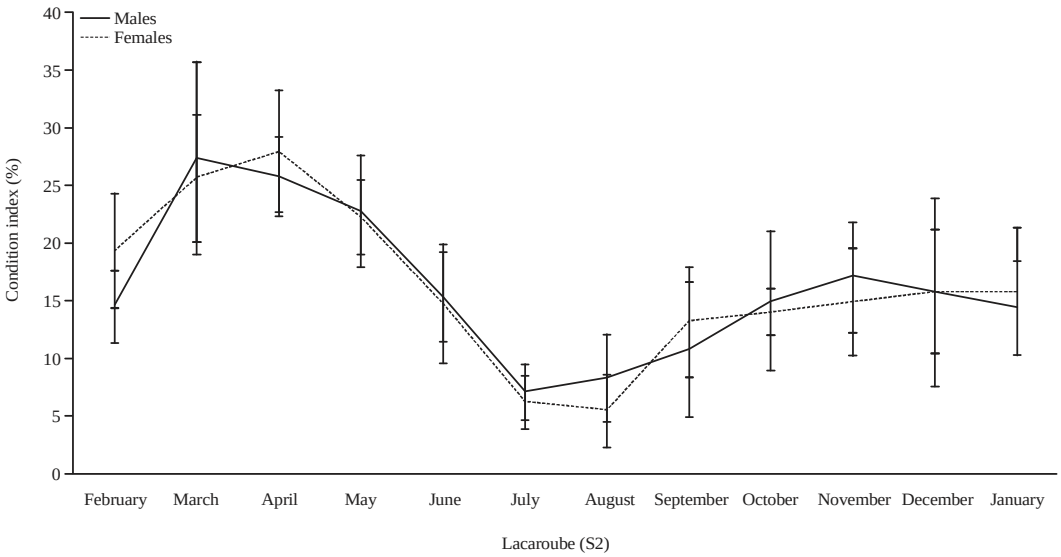

Fig. 3: Temporal variation in the condition index at station 2 (Gulf Annaba, February, 2012-January, 2013)

Table 3: Matrix of correlations between physico-chemical parameters and condition index

Parameters	CI of males	CI of females	Temperature	pH	Salinity
CI of females					
r-value	0.937				
p-value	0.000				
Temperature					
r-value	-0.503	-0.565			
p-value	0.002	0.000			
pH					
r-value	0.535	0.541	-0.565		
p-value	0.001	0.001	0.000		
Salinity					
r-value	-0.237	-0.150	0.172	-0.169	
p-value	0.164	0.384	0.315	0.323	
Dissolved oxygen					
r-value	0.520	0.533	-0.386	0.336	-0.052
p-value	0.001	0.001	0.020	0.045	0.761

Table 4: Spatial distribution of the sex-ratio of the sea urchin *Paracentrotus lividus* in the Gulf of Annaba

	Effective					
Stations	Females	Males	Indeterminate	Rate of femininity (%)	Rate of masculinity (%)	Sex-ratio (%)
S1	185	164	11	53.00	46.99	46.99
S2	207	133	20	60.88	39.11	39.11
S3	184	172	4	51.68	48.31	48.31

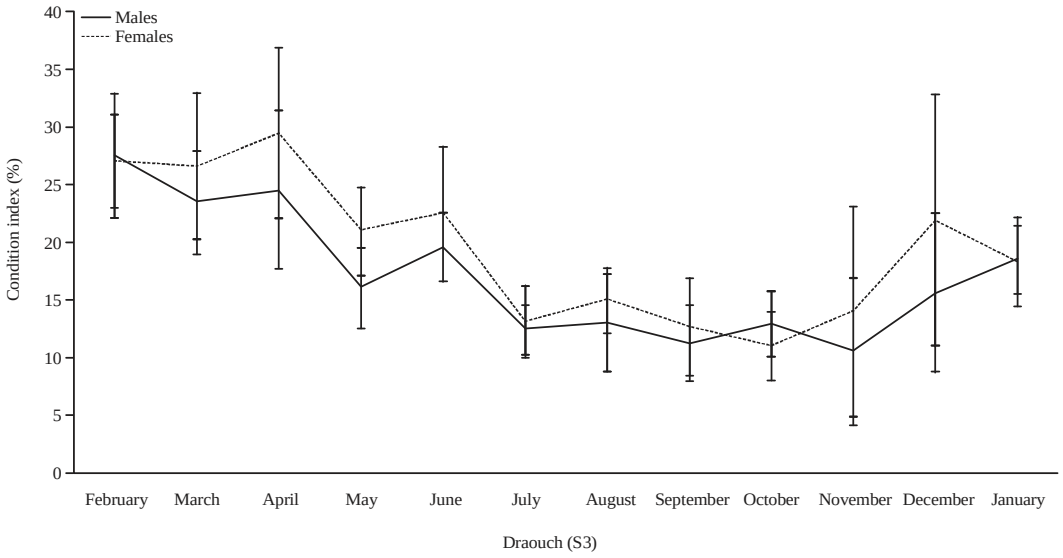

Fig. 4: Temporal variation in the condition index at station 3 (Gulf of Annaba, February, 2012-January, 2013)

April for males and females with values in the ranges of 24.55±6.89 and 29.48±7.33%, respectively (Fig. 4). However, the minimum was found in November for males (10.53±6.38%) and in the month of October for females (11.04±2.98%).

Pearson simple linear correlations between five biotic and abiotic variables taken two by two compared to the total population was calculated. It should be noted that these correlation coefficients measure the strength of the linear relationship between the variables taken two by two. The results of this analysis are shown in Table 3. The results clearly indicate the presence of a proportional correlation between the variation of the male CI and the female CI. The results as a correlation between the change in condition indices of both sexes (male and female) and abiotic parameters (pH and dissolved oxygen) was obtained. However, no correlation of this index with salinity was reported.

The gender distribution of the population of *Paracentrotus lividus* is given in Table 4. The values obtained show a dominance of females compared to males

at the 3 stations in the Gulf of Annaba. However, the statistical analysis indicates that the sex-ratio is not different from the theoretical proportion of 50% for station S1 ($\chi^2 = 0.628$, $p = 0.427$) and station S3 ($\chi^2 = 1.697$, $p = 0.192$). But at station S2 significant differences were found between the proportions of both sexes ($\chi^2 = 4.564$, $p = 0.032$).

DISCUSSION

The variation of marine abiotic parameters has a considerable effect on the structure and functions of many aquatic organisms and the environmental factors affecting the modalities of sea urchin reproduction have been extensively covered in the literature[26]. The measurement of the physicochemical parameters revealed that the waters at the 3 sampling stations were favorable for the development of the sea urchin *Paracentrotus lividus*. The latter mainly colonizes temperate regions where thermal conditions fluctuate between 10 and 15°C in winter and 18 and 25°C in summer[27]. The temperature may influence spawning and previous studies on *Paracentrotus lividus* highlighted that rising sea temperatures may serve as a proximate cue for the induction of spawning[4]. Temperature also can affect spawning duration and thus act directly on gonad growth and nutrient accumulation, permitting gametogenesis[21]. Sea temperatures may also influence gonad growth by acting directly on food availability and food intake.

Sea urchins can develop adaptive mechanisms to changes in the physicochemical parameters of water and adult urchins can regulate the ion concentrations in their extracellular fluid to deal with changes in pH[28]. Moreover, they have low respiratory rates due to the diffusion of low amounts of oxygen in their tissues. This is also the case for salinity. Sea urchins inhabiting shallow coastal waters where the salinity fluctuations occur[29] have highly improved osmoregulatory characteristics[30,31]. The condition index is an indicator of the physiological state of individuals[32,33], it gives an idea of the state of health of the individuals of a population[34]. At the three research stations, the condition index indicated a fairly pronounced monthly change, the increase in the condition index in spring could be explained by hypertrophy of the gonads and the storage of nutrients.

The results of Lawrence and Guille[35], Fernandez[36] and McClintock and Pearse[37] showed that the biochemical components of the gonads vary according to season.

Spirlet *et al.*[38] focused on the existence of a relationship between the period of reproduction in the echinoids inhabiting temperate regions and the period of storage of nutrients. McQuaid and Lawrie[39] explained that the increase in the condition index signals the maturation of the gonads and the accumulation of reserves. However, its decrease indicates the emission of gametes[40]. The occurrence of a period of high planktonic productivity was identified as important for the process of gonadal maturation of the sea urchin[41].

These results also revealed that the growth of individuals following a rhythm that differed from one station to another, certainly imposed by the quality of the environment, indicated that sea urchins can delay their reproduction. This conclusion is based on the comparison of our seasonal observations and as a function of weather conditions[42]. Our findings are supported by the study of Byrne[43] which showed atrophy of the gonads in urchins harvested in intertidal areas poor in nutritional matter. The proportion of the sexes is a characteristic of the species whose variations are sometimes linked to environmental factors.

According to Kartas and Quignard[44], the sex ratio is one of the parameters that contribute to maintaining this species' capacity of reproduction. This index represents the abundance of one sex compared to the other[8]. At the level of the sampling stations, only station S2 presented an imbalance between the sexes in favor of females. This has already been observed by Dermeche *et al.*[20], Guettaf *et al.*[22], Semroud and Senoussi[45] and Neefs[46]. This difference could be explained by a high mortality rate and/or a difference in the growth rate[47].

CONCLUSION

The results obtained showed that the physico-chemical parameters of the waters of the Gulf of Annaba are favorable for the development of the sea urchin *Paracentrotus lividus*. In addition, it was observed that a similar trend in the variation of the condition index in both sexes of the sea urchin *Paracentrotus lividus* and that physiological status was maximum in spring, probably due to high consumption in winter and the breeding period. On the other hand, population structure varied from one station to another, probably due to environmental constraints.

SIGNIFICANT STATEMENTS

Sea urchin gonads can be used as antioxidants in a manner similar to other polyphenolic components from plants. The researchers focused on such bio-macromolecules accumulated as nutrients during gametogenesis. The use of these sources of natural antioxidants could contribute to the development of echino culture. The highlights of this study are:

- It shows the effect of abiotic parameters on the physiological state of the sea urchin
- It uses population structure to indicate imbalances in favor of either gender
- It identifies the period of gametogenesis in males and females
- It identifies the period of gonad maturity and nutrient accumulation

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