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## HOW A BIOINDICATOR (OR COSMOPOLITE) COPEPOD VARY BETWEEN RESERVOIRS OF DIFFERENT TROPHIC STATE? A CASE FROM ALGERIA

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**RÉSUMÉ.**— *Comment un copépode bioindicateur (ou cosmopolite) varie-t-il dans des réservoirs de qualité trophique différente ? Un cas en Algérie.*— Les effets de paramètres physicochimiques sur la dynamique d'*Acanthocyclops robustus* dans quatre réservoirs (Kedarra, Gargar, Cheurfas II et Ghrib) situés dans les régions de l'ouest et du centre de l'Algérie ont été étudiés. Des échantillons d'eau ont été prélevés saisonnièrement le long d'une année. Les densités d'*A. robustus* n'étaient pas stables au cours de l'année ; elles dépendaient des variations des facteurs environnementaux. Des tests statistiques ont été utilisés pour démontrer les interactions entre les paramètres environnementaux et la densité d'*A. robustus*. Il y avait une hétérogénéité dans les paramètres physico-chimiques mesurés selon les réservoirs. L'indice de pollution organique des eaux du réservoir variait entre 2,5 (forte pollution organique) et 3,75 (pollution organique modérée). *Acanthocyclops robustus* est une espèce pérenne dans les quatre réservoirs. La densité de l'espèce variait selon l'échelle spatio-temporelle ; la densité la plus élevée a été observée à Kedarra (317,542 ind./L) et la plus faible a été trouvée dans le réservoir de Cheurfas II (41,692 ind./L). Les résultats ont montré que l'espèce était très sensible à l'eutrophisation ; sa densité était corrélée positivement avec la transparence et l'indice de pollution organique, mais négativement avec la conductivité, le calcium, les matières en suspension, NH<sub>4</sub> et DBO<sub>5</sub>.

**SUMMARY.**— The effects of physicochemical parameters on the dynamics of *Acanthocyclops robustus* in four reservoirs (Kedarra, Gargar, Cheurfas II, and Ghrib) located in the western and central regions of Algeria were studied. Water samples were taken seasonally along a year. The densities of *A. robustus* were not stable during the year; they depended on variations in the environmental factors such as the transparency of water, orthophosphates, conductivity, BOD<sub>5</sub>, and nutrients. Statistical tests were used to demonstrate the interactions between the environmental parameters and *A. robustus* density. There was heterogeneity in the physicochemical parameters measured among the reservoirs. The organic pollution index of the reservoir waters ranged between 2.5 (strong organic pollution) and 3.75 (moderate organic pollution). *Acanthocyclops robustus* was a perennial species in all four reservoirs. The density of the species varied at a spatiotemporal scale; the highest levels were observed at Kedarra reservoir (317,542 ind./L) and the lowest density was found at Cheurfas II reservoir (41,692 ind./L). Results showed that the species was very sensitive to eutrophication; its density was positively correlated with transparency and the organic pollution index, and negatively with conductivity, calcium, suspended matter, NH<sub>4</sub>, and DBO<sub>5</sub>. The OPI highlighted the pollution levels of the different reservoirs studied. The study of *A. robustus* dynamics showed that the species is strongly affected by ecological factors.

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In Algeria, aquatic ecosystems are becoming more degraded than ever, because of large quantities of untreated pollutants that are discharged into them. Studies of species and the factors that govern their existence are based on analyses of the distributions of species abundance and the hydrological parameters that influence them. The synthetic approach of the stands makes it possible to emphasize their spatial and temporal instability and then link this to water movement (Lam Hoai & Amanieu, 1989). Intensive farming, fishing, sand extraction, domestic effluent discharges, roads and dams are among the main disturbances that affect water quality and stream morphology. Eutrophication and changes in stream dynamics are consequences of these disturbances (Aguilar-Ibarra, 2004; Chikou, 2006 in Zinsou *et al.*, 2016).

This study focused on a dominant freshwater species within zooplankton assemblages, *Acanthocyclops robustus*. It is a copepod crustacean which belongs to the Cyclopidae family (Sars, 1863; Kiefer, 1927). According to Perbiche-Neves *et al* (2016), it is a bioindicator species for eutrophication in reservoirs, indeed Bidi-Akli *et al.* (2014) showed that the species is resistant to eutrophication. Its abundance could be used to monitor water bodies and predict potential impacts on water quality. *Acanthocyclops robustus* was found to be a primary intermediate host for *Coelomomyces punctatus*, in an epizootic that affected a larval mosquito population of *Anopheles quadrimaculatus* (Apperson *et al.*, 1992). It can also be infected by the larvae of *Anguillicola crassus*, an endoparasite that colonizes the abdominal cavity of the eel and then attaches to its swim bladder (Hubbard *et al.*, 2016). It is also an intermediate host for fish parasites as indicated by Piasecki *et al.* (2004). From an economic point of view, it plays an important role in aquaculture. In fish farming *A. robustus* individuals are micro-predators and predators of fish larvae (especially Cyprinidae) and their prey (e.g., Rotifera) (Piasecki, 2004; Bidi-Akli *et al.*, 2014). In algae farming (the cultivation of microalgae), the continuous introduction of *A. robustus* in rotifer-infected crops helps control the abundance of rotifers and thus improves algal production (Smith, 2014). As other cyclopoids, *A. robustus* is cannibalistic, in that it feeds on its own nauplii (Garcia-Chicote, 2007).

In this study, we evaluated the variation of physicochemical parameters in 4 reservoirs, to study the dynamics of *A. robustus*, during a one-year cycle.

## MATERIALS AND METHODS

### STUDY AREA

This study focused on four reservoirs in the western and central regions of Algeria (Fig. 1). The water bodies belonged to three different bioclimatic areas: (i) sub-humid to temperate winter (Keddara), the dry season runs from May to October, i.e. five months; (ii) arid to temperate winter (Cheurfas II and Gargar), the dry period lasts for 6 months, from April to October; (iii) semi-arid to temperate winter (Ghrib) with a dry period from mid-February to the end of October. The geographical coordinates and the characteristics of the dams are given in Table I below.

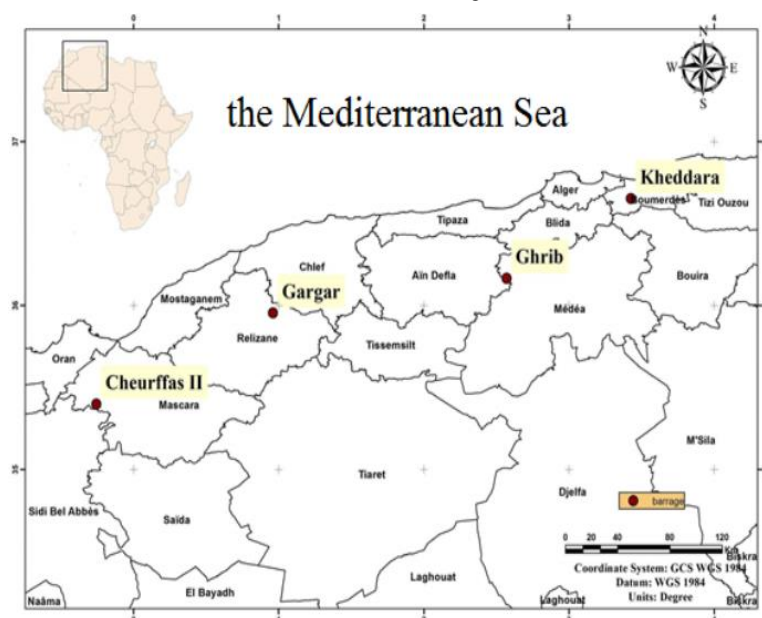


Fig. 1. Locations of the four reservoirs studied.

TABLE I  
*Geographical coordinates and characteristics of the dams*

Dam	Latitude	Longitude	Altitude (m)	Affectation	Source of pollution	Trophic status
Cheurfia II	35°24'11"N	00°15'15"W	201	irrigation, accumulation basin	wastewater and industrial waste	hypereutrophic
Gargar	35°57'45"N	00°57'48"E	135	drinking water supply and irrigation	nothing	meso-eutrophic
Ghrib	36°09'47"N	02°33'38"E	409	drinking water supply and irrigation	domestic waste water	eutrophic
Keddara	36°39'41"N	03°25'41"E	222	drinking water supply and irrigation	nothing	mesotrophic

#### SAMPLING AND ANALYSIS

Generally, the quality of surface waters is assessed based on the measurement of physicochemical parameters and the presence or absence of aquatic organisms and microorganisms that are indicators of water quality (Bli-Effert & Perraud, 2001). In this study, water sampling was done in each season during 2010, at three locations in each reservoir (left bank, right bank and center of the reservoir).

Five water parameters (dissolved oxygen, temperature, pH, salinity and conductivity) were measured *in situ* using a multi-parameter trend wtw 340i field analyzer. Transparency was also obtained, in meters, using a Secchi disc. Water samples were taken using a 1 L Niskin rollover and a zooplankton net of 55 µm mesh size was used to collect the plankton.

Parameters in the water samples were measured in the laboratory on the same day as sampling, using methods described by Rodier (1984, 2009); we used filtration for suspended matter, titration for carbonates, the gravimetric method for calcium and magnesium, the volumetric method for chlorides, and the colorimetric method for phosphates and nitrogen compounds. The sorting and identification of *A. robustus* was performed at the Laboratory of Dynamics and Biodiversity in the university of Sciences and Technology Houari Boumediene, using a binocular lens and optical microscope with Dussart (1969) keys.

#### STATISTICAL ANALYSIS

Zooplankton-physicochemical relationships were evaluated by Principal Component Analysis (PCA). We used a generalized linear model (GLM), which is a flexible approach that relates the response variable by a link function to the independent variables (Zeileis *et al.*, 2008). Analysis of variance (ANOVA) was also used to confirm the heterogeneity in the distribution of *A. robustus* over time and the heterogeneity of concentrations of physicochemical parameters inter the 4 reservoirs, and we used the Shapiro-Wilk normality test. A logarithmic transformation was performed prior to the matrix of quantitative variables to ensure compliance with normality hypothesis (Koji *et al.* 2017). Analyses heterogeneity were conducted in xIstat software.

### RESULTS

#### ABIOTIC PARAMETERS

The physicochemical parameters of the reservoir waters are presented in Table II. There was heterogeneity between the reservoirs, to confirmed it we used ANOVA (Tab. III). According to the Shapiro-Wilk normality test, the pH, water temperature, transparency, dissolved oxygen, suspended matter, and nitrates correspond to a normal distribution (P-value > 5 %, Tab. II). Conductivity, nitrites, and orthophosphates do not follow a normal distribution (P-value < 5%, Tab. II).

#### ACANTHOCYCLOPS ROBUSTUS ABUNDANCE

##### *Seasonal changes of A. robustus*

The seasonal mean densities of *A. robustus* observed in the four reservoirs are shown in Tab. IV; *A. robustus* was present throughout the sampling period in all four reservoirs. indicating that it is a perennial species.

In general, the density of *A. robustus* varied from one season to another; it was higher during spring in the Cheurfas II and Ghrib reservoirs, during autumn in Kedarra reservoir, and during winter in Gargar reservoir (Fig. 2).

The ANOVA analysis used to test the seasonal effects on the dynamics of *A. robustus* showed a significant difference in the density of *A. robustus* among the four dams with respect to season

(Tab. V). The null hypothesis was rejected; therefore, we considered the alternative hypothesis which showed there was a significant difference in the density of *A. robustus* among the seasons.

TABLE II

*The seasonal mean values of the physicochemical parameters studied in the four reservoirs*

	T	pH	Cond	Trans	O <sub>2</sub>	MES	NO <sub>3</sub>	NO <sub>2</sub>	PO <sub>4</sub>
KadSp	23.15	8.54	1009	2.24	8.38	13.81	1.38	0.06	0.10
KadS	42.46	8.40	955	3.56	6.06	10.22	2.72	0.03	0.13
KadA	18.21	8.21	944	2.38	7.71	13.75	2.61	0.02	0.08
KadW	15.55	8.18	973	1.42	7.98	43.68	4.29	0.01	0.101
CheuSp	24.97	8.88	2440	0.55	10.68	76.67	1.30	0.04	0.13
CheuS	22.27	8.76	2786	0.53	13.72	76.67	1.06	0.06	0.10
CheuA	15.63	8.30	2603	0.17	4.44	200	0.13	0.03	0.30
CheuW	12.43	7.93	2986	0.12	2.89	223.33	2.58	2.93	2.34
GarSp	18.4	8.34	1946	1.175	10.82	118.75	0.44	0.01	0.17
GarS	26.69	8.52	1795	0.58	10.09	22.71	1.66	0.05	0.27
GarA	20.38	7.95	2111	0.5	8.10	278.35	0.66	0.05	0.01
GarW	11.47	8.31	1888	0.31	7.29	201.07	4.08	0.06	0.01
GhrSp	22.53	8.12	1500	1.05	6.67	33.57	2.75	0.10	0.37
GhrS	26.67	8.32	3003	1.24	6.64	33.64	1.74	0.15	0.28
GhrA	15.59	8.12	3474	0.75	5.46	38.82	1.60	0.09	0.29
GhrW	11.95	7.94	3181	0.72	7.78	25.02	2.99	0.10	0.33
Shapiro-Wilk normality test	0.5254	0.1492	0.04039	0.3684	0.6844	0.2981	0.676	2.277e-07	1.935e-05

T. water temperature (°C); Cond. electrical conductivity (s/μcm); Trans. transparency (m); O<sub>2</sub>. dissolved oxygen (mg/L); MES. suspended matter (mg/L); NO<sub>3</sub>. nitrates (mg/L); NO<sub>2</sub>. nitrites (mg/L); PO<sub>4</sub>. orthophosphates (mg/L); Kad. Keddarra; Cheu. Cheurfas II; Gar. Gargar; Ghr. Ghrib; Sp. spring; S. summer; A. autumn; W. winter

TABLE III

*Application of the ANOVA to physicochemical parameters*

	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	6,18431E07	8	7,73039E06	92,82	4,571E-51
Within groups:	1,12433E07	135	83284		Permutation p(n=99999) 1E-05

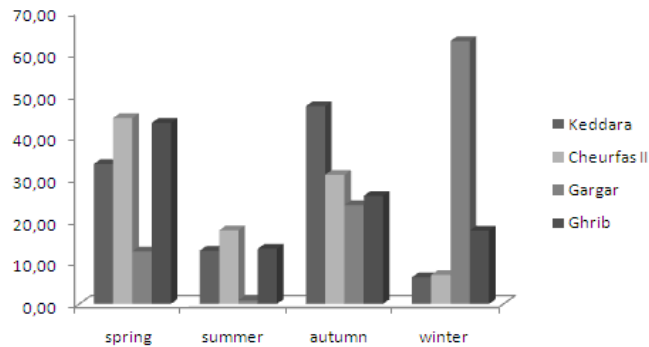


Figure 2.— Seasonal dominance (%) of *Acanthocyclops robustus* in each dam.

TABLE IV

*Seasonal changes in the density of *A. robustus**

Dam		Density (ind/L) according to Season			
		Spring	Summer	Autumn	Winter
	Keddarra	106.358	40.539	150.388	20.257
	Cheurfas II	18.562	7.339	12.891	2.900
	Gargar	12.876	0.880	24.220	64.560
	Ghrib	27.168	8.279	16.218	11.00

TABLE V

Results of the ANOVA on the effects of season on the density of *A. robustus*

Source	DDL	Sum of squares	Average of squares	F	Pr > F
Model	3	12550358688.056	4183452896.019	4.908	0.003
Error	112	95463416329.327	852351931.512		

*Impact of abiotic factor on the abundance of Acanthocyclops robustus*

To study the interactions between the water quality parameters measured and the density of *A. robustus*, we used PCA. Figure 3 shows the graph obtained by the PCA which explains 58.82 % of the information given by the first two factors (axis 1 = 38.71 % and axis 2 = 20.10 %). According to the first axis, the abundance of *A. robustus* is positively associated with transparency of water and organic pollution index, and it is negatively associated with the conductivity, salinity, suspended matter,  $\text{NH}_4$ ,  $\text{DBO}_5$  and calcium.

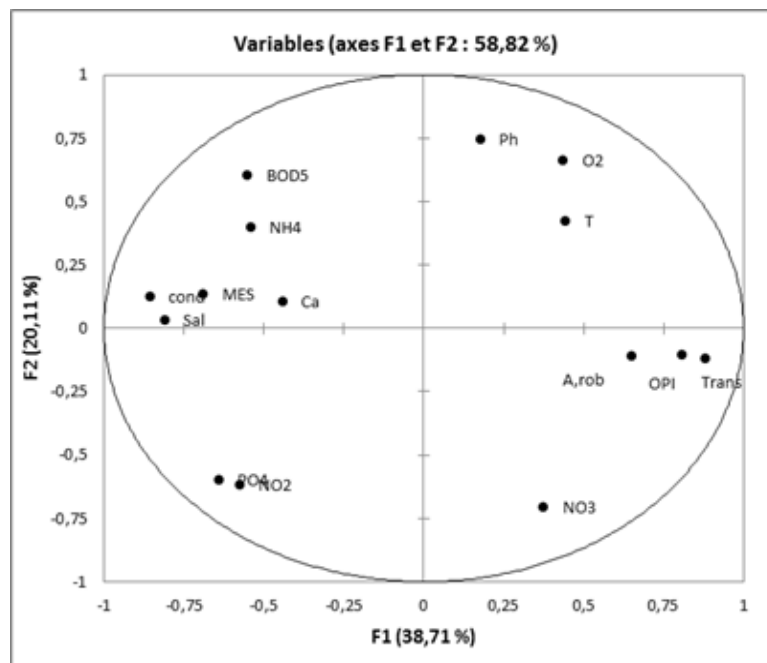


Figure 3.— PCA projections of the variables on the axes F1 and F2 (inertia = 58.82 %).

On the second axis, O<sub>2</sub> has a positive coordinate and is correlated to pH and temperature of water, and is negatively associated with NO<sub>3</sub>, NO<sub>2</sub> and PO<sub>4</sub>.

The correlation matrix in Table VI shows that the abundance of *A. robustus* had significant positive relationships with transparency and the OPI. Significant negative correlations were observed between the abundance of *A. robustus* and parameters of pollution, both conductivity, salinity, calcium levels, MES, NO<sub>2</sub>, PO<sub>4</sub>, NH<sub>4</sub> and BOD<sub>5</sub>.

The projection of the *A. robustus* density data for each reservoir in each season on the factorial plane F1xF2 showed a spatiotemporal gradient for the variations in *A. robustus* density with respect to the physicochemical parameters (Fig. 4). On the first axis, Kedarra reservoir samples from all four seasons are gathered in the positive part whereas summer and autumn samples from Ghrib and winter samples from Cheurfas II constitute another group in the negative

part. Along the second axis, Cheurfas II and Gargar spring, summer and autumn samples are grouped in the positive part whereas spring and winter samples from Ghrib and winter samples Gargar are grouped in the negative part.

TABLE VI

Correlation matrix between environmental and biotic parameters In bold significative values

Parameters	T	pH	Cond	Sal	Trans	O2	MES	NO3	NO2	PO4	NH4	BOD5	Ca	OPI	A. rob
T	<b>1</b>	<b>0,501</b>	-0,373	-0,296	<b>0,579</b>	0,317	<b>-0,509</b>	-0,172	-0,335	-0,307	-0,225	0,099	-0,007	0,108	0,004
Ph	<b>0,501</b>	<b>1</b>	-0,058	-0,121	0,057	<b>0,605</b>	-0,153	-0,299	-0,363	-0,383	0,107	0,391	-0,286	-0,109	-0,067
Cond	-0,373	-0,058	<b>1</b>	<b>0,910</b>	<b>-0,760</b>	-0,164	<b>0,521</b>	-0,346	0,317	0,384	0,342	0,381	<b>0,557</b>	<b>-0,650</b>	<b>-0,569</b>
Sal	-0,296	-0,121	<b>0,910</b>	<b>1</b>	<b>-0,688</b>	-0,264	0,394	-0,214	0,284	0,403	0,372	0,219	<b>0,642</b>	<b>-0,693</b>	-0,465
Trans	<b>0,579</b>	0,057	<b>-0,760</b>	<b>-0,688</b>	<b>1</b>	0,176	<b>-0,803</b>	0,271	-0,382	-0,384	-0,491	<b>-0,566</b>	-0,357	<b>0,558</b>	<b>0,553</b>
O2	0,317	<b>0,605</b>	-0,164	-0,264	0,176	<b>1</b>	-0,185	-0,161	-0,651	<b>-0,700</b>	-0,266	0,072	0,038	0,382	0,054
MES	<b>-0,509</b>	-0,153	<b>0,521</b>	0,394	<b>-0,803</b>	-0,185	<b>1</b>	-0,378	0,340	0,244	0,418	<b>0,684</b>	0,071	-0,294	-0,234
NO3	-0,172	-0,299	-0,346	-0,214	0,271	-0,161	-0,378	<b>1</b>	0,173	0,108	<b>-0,584</b>	<b>-0,658</b>	-0,171	0,380	0,203
NO2	-0,335	-0,363	0,317	0,284	-0,382	<b>-0,651</b>	0,340	0,173	<b>1</b>	<b>0,946</b>	-0,067	0,154	-0,087	<b>-0,508</b>	-0,381
PO4	-0,307	-0,383	0,384	0,403	-0,384	<b>-0,700</b>	0,244	0,108	<b>0,946</b>	<b>1</b>	0,045	0,085	0,079	<b>-0,593</b>	<b>-0,506</b>
NH4	-0,225	0,107	0,342	0,372	-0,491	-0,266	0,418	<b>-0,584</b>	-0,067	0,045	<b>1</b>	<b>0,521</b>	0,105	<b>-0,578</b>	-0,136
BOD5	0,099	0,391	0,381	0,219	<b>-0,566</b>	0,072	<b>0,684</b>	<b>-0,658</b>	0,154	0,085	<b>0,521</b>	<b>1</b>	-0,002	-0,480	-0,405
Ca	-0,007	-0,286	<b>0,557</b>	<b>0,642</b>	-0,357	0,038	0,071	-0,171	-0,087	0,079	0,105	-0,002	<b>1</b>	-0,298	<b>-0,575</b>
OPI	0,108	-0,109	<b>-0,650</b>	<b>-0,693</b>	<b>0,558</b>	0,382	-0,294	0,380	<b>-0,508</b>	<b>-0,593</b>	<b>-0,578</b>	-0,480	-0,298	<b>1</b>	<b>0,535</b>

T. water temperature; Cond. electrical conductivity; Sal. salinity; Trans. transparency; O<sub>2</sub>. dissolved oxygen; MES. suspended matter; NO<sub>3</sub>. nitrates; NO<sub>2</sub>. nitrites; PO<sub>4</sub>. orthophosphates; NH<sub>4</sub>. ammonium; BOD<sub>5</sub>. 5-day biological oxygen demand; Ca. calcium; OPI. Organic pollution index; A. rob. *Acanthocyclops robustus*.

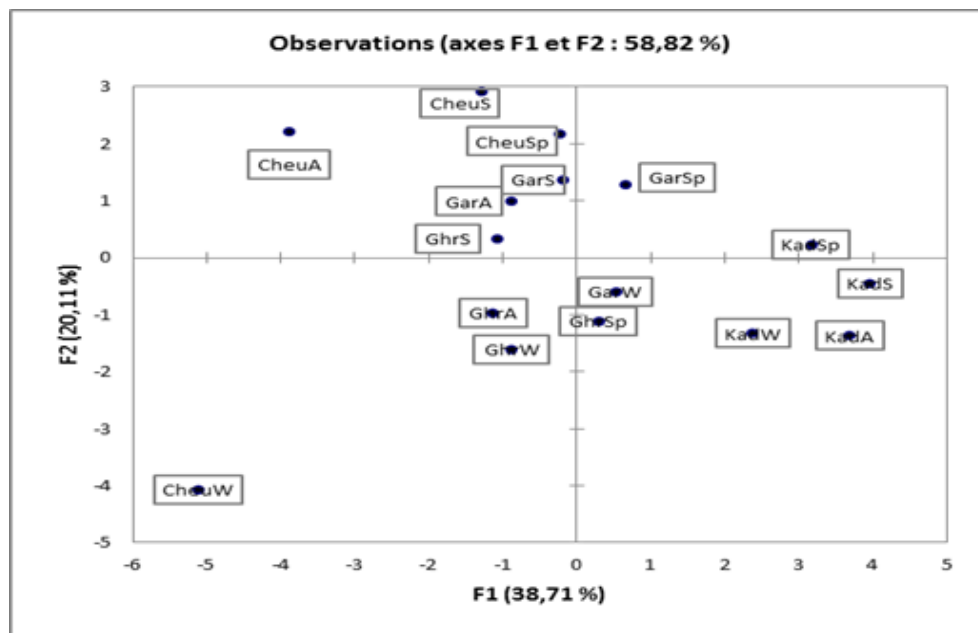


Figure 4.— Projection of the samples from the reservoirs on the two factorial planes (inertia 71.35 %). Kad. Keddarra; Cheu. Cheurfas II; Gar. Gargar; Ghr. Ghrib; Sp. spring; S. summer; A. autumn; W. winter

These trends are consolidated by Generalized Linear Models. Indeed, the results in Table VII revealed that the conductivity, salinity, transparency, calcium, bicarbonate, and organic pollution index had a significant effect ( $p\text{-value} > 0.05$ ) on the variations of abundance of *Acanthocyclops robustus*. On the reverse, the pH, O<sub>2</sub>, MES, SO<sub>4</sub>, Mg, Cl and temperature did not display a significant effect ( $p\text{-value} < 0.05$ ).

TABLE VII  
Results of the generalized linear model

Variable	Slope	Error	Intercept	Error	r	p
pH	-0,00027	0,0069	0,92	0,029	-0,010	0,97
Cond	-0,20	0,079	4,16	0,34	-0,57	<b>0,020</b>
Sal	-0,26	0,12	1,04	0,52	-0,50	<b>0,047</b>
Trans	0,37	0,17	-1,68	0,70	0,51	<b>0,043</b>
O <sub>2</sub>	0,02	0,078	0,78	0,33	0,068	0,80
MES	-0,20	0,21	2,58	0,93	-0,24	0,37
So <sub>4</sub>	0,16	0,33	1,58	1,40	0,13	0,64
Ca	-0,23	0,088	3,18	0,37	-0,57	<b>0,019</b>
Mg	-0,02	0,073	2,04	0,31	-0,08	0,77
HCO <sub>4</sub>	1,73	0,56	-7,5	2,41	0,63	<b>0,008</b>
Cl	-0,066	0,22	2,54	0,95	-0,078	0,77
OPI	0,058	0,025	0,26	0,10	0,53	<b>0,035</b>
T	-0,003	0,073	1,30	0,31	-0,01	0,97

## DISCUSSION

### SPATIOTEMPORAL VARIATION IN *A. ROBUSTUS*

The geological composition of the watershed differs from one reservoir to another one. This influenced the physicochemical quality of the water and biotic diversity among the four reservoirs. The seasonal monitoring of *A. robustus* density showed a heterogeneity in the dynamics of the species with strong ecological effects. Bioclimatic factors, physicochemical parameters, biological composition of the reservoirs, and the constitution of the various links in the food chains influenced the heterogeneity. Perbiche-Neves *et al.* (2007) and Nishimura *et al.* (2014) also found instability in *A. robustus* at the spatiotemporal scale in eutrophic and hypereutrophic environments. Perbiche-Neves *et al.* (2007) reported high abundances of *A. robustus* during March (1284 ind./m<sup>3</sup>) and April (1545 ind./m<sup>3</sup>) and higher densities in December with an increase in rainfall. A study of seasonal variations in zooplankton grazing on the phytoplankton of the Al Massira dam reservoir (Morocco) showed low densities of *A. robustus* in summer compared to winter and spring (Mokhliss *et al.*, 2001). These seasonal variations were attributed to certain abiotic factors, such as temperature, pH and dissolved oxygen, and biological factors, including the specific composition and abundance of the phytoplankton populations (the first link in the trophic chain).

Conversely, Gaudy (1971), Johnson (1979), Moncef (1993) and Stearns *et al.* (1989) noted that the abundance of most copepod species decreased in winter, with even some disappearing from the water column, while in summer copepod abundances were highest, which may have resulted from thermal conditions being favourable to the reproduction and development of zooplankton. El Khalki & Moncef (2006) concluded that a significant contribution of nutrient salts to the surface was responsible for an increase in primary production. These trophic conditions, combined with the effects of temperature, would contribute to optimal secondary production in summer, leading to an increase in copepod density during summer. This relative stability from one year to the next, observed a long time ago by Spillmann (1940), is to be compared with that of the physicochemical characteristics of water. It would therefore be interesting to specify the possible relationships between the succession of cladoceran and copepod species and the evolution of environmental conditions.

### IMPACT OF PHYSICOCHEMICAL PARAMETERS ON THE ABUNDANCE OF *A. ROBUSTUS*

In our studies, the abundance of *Acanthocyclops robustus* was sensible to water pollution. In Kedarra, abundance of this species was higher than in other dams, because it had high values for transparency and the concentrations of nutrient salts were low compared to other dams. The trophic state of this dam is mesotrophic, whereas Ghrib dam is eutrophic with high concentrations



of phosphorus, Gargar dam is meso-eutrophic, while Cheurfas dam is hypereutrophic. Principal Component Analysis (PCA), allowed us to classify dams relative to their degree of pollution. Cheurfas II and Gargar, were more exposed to pollution caused by conductivity, salinity, suspended matter,  $\text{NH}_4$ ,  $\text{DBO}_5$  and calcium.

Santos-Wisniewski & Rocha (2007) suggested that copepod production was supported by primary production, temperature, nutrient concentrations and chlorophyll. Perbiche-Neves *et al.* (2007) reported that the abundance of *A. robustus* was indirectly correlated with several variables, including rainfall, nitrite, nitrate, turbidity, dissolved oxygen, conductivity and chlorophyll *a*. According to our results, the dynamics of *A. robustus* depended positively on variations in water transparency and organic pollution index, and negatively with conductivity, salinity, suspended matter,  $\text{NH}_4$ ,  $\text{DBO}_5$  and calcium. Density was higher when water transparency was high and concentrations of orthophosphates and nutrient salts were low, which makes us think that *A. robustus* is sensitive to eutrophication. Perbiche-Neves *et al.* (2016) studied *A. robustus* as a bioindicator of eutrophication and indicated that the species evolves in eutrophic environments with elevated nutrient and phosphorus loads, with positive effects of total phosphorus and chlorophyll *a* on the density of the species.

Our study showed negative effects of salinity and conductivity on the abundance of *A. robustus*; the coefficient of the correlation obtained was -0.57. Studies that have found similar results include that of Matsumura-Tundisi & Tundisi (2005), who showed a marked effect of electrical conductivity on *Calanoida*. Lucena-Moya & Duggan (2016) also reported salinity as a major factor influencing the composition and diversity of zooplankton communities. Another study tested whether the variability in zooplankton assemblages was compatible with categories proposed by the environmental classification system in an estuary (Hume *et al.*, 2007); the study classified *A. robustus* in the freshwater category. The response of zooplankton to salinity gradients is not just a matter of species osmoregulation, but salinity is also associated with environmental and hydrodynamic characteristics, with ecological consequences for *A. robustus* (David *et al.*, 2016).

## CONCLUSIONS

This work has indicated variations of *A. robustus* abundance in relation to environmental parameters and their seasonal variations among four reservoirs in Algeria. The OPI highlighted the pollution levels of the different reservoirs studied. Our study of *A. robustus* dynamics showed that the species is strongly affected by ecological factors. Its abundance was unstable over time and the results of the PCA showed that the species is sensitive to eutrophication.

We consider it important to extend our study by investigating the effects of chlorophyll *a* and phytoplankton community on *A. robustus* dynamics and to model the interactions between abundance and evolution of *A. robustus* populations and the spatiotemporal variations of the physicochemical parameters and phytoplankton community.

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