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Scenario for parasitic infestation of the European eel (*Anguilla anguilla* L.) in Oubeïra Lake (northeastern Algeria)

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Abstract

This work describes the parasitic fauna of the European eel living in Oubeïra Lake (Northeastern of Algeria), with a special focus to the temporal dynamic of the parasites –never approached previously. A total of 450 specimens of European eel *Anguillaanguilla* L. 1758, were sampled during 3 years (between November, 2010 and April, 2012) in Oubeïra Lake (Park national of El Kala, Northeastern of Algeria). The environmental parameters were measured in situ. The biometric characters of fish (length, weight, horizontal and vertical diameters of the eyes and the length of the pectoral fin) were taken, prior to dissection. Species identification was done when possible and classical epidemiological parameters were calculated. The total macroparasite richness was 6 species: 2 Crustacean; 1 Monogenea, 1 Cestoda and 2 Nematoda. According to the epidemiological index, *E. gibbus* was the most common (83.40±14.9%), followed by both nematodes (50% of the captured fish). Our assessment of the EELREP Silvering index revealed that 95.78% were females, of which more than 50% were silvered and these sheltered the most parasites. The prevalence of three species (monogenean, cestode and copepod) is significantly different in the same month between years. Significant positive relationships between *A. crassus*, *B. claviceps* and *Pseudodactylogyrus* sp. abundance were observed.

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Introduction

Parasitism is an interaction of particular interest to ecologists and parasitology provides a multidisciplinary approach to investigating host-parasite interactions including the elegant strategies parasites have evolved to survive and replicate within their hosts.

The effects of parasitism are considered instrumental in influencing fundamental aspects of host biology, including host behavior, the evolution of sex, variation in mating systems and life history strategies and invasion dynamics (Anderson and May, 1978; Hamilton, 1980; Poulin, 2007; Schmid-Hempel, 2010). Identifying the conditions that alter the relative advantage of hosts and parasites is a coevolutionary arms race that is central to our understanding of pathology (Woolhouse *et al.,* 2002).

Therefore, to make accurate predictions concerning how parasite communities respond to perturbations, it is necessary to understand the mechanisms and environmental conditions which affect the interactions between component species and individual hosts (cf. Pederson and Fonten, 2007).

In our study area, parasitism traditionally was used to address the rate of infestation as well as classical counting of the parasites without considering the micro-organism component and their interaction with their host.

These approaches provided a basic description of parasite communities at the host population level but they provide little mechanistic insight into the within-host effects or with other interactions and relationships.

In this paper, we address these additional aspects and explore the temporal dynamics of species interactions, their relationship with morphometric characters of the host and the environmental factors as these are crucial for better understanding of community dynamics in this region.

Materials and methods

Study area

Lake Oubeïra is a fresh water ecosystem not connected to the sea, with a surface area of 2.200 hectares, and 4m depth. It is located approximately 4 km from the Mediterranean Sea shore, at N36°50, E08°23 (Fig. 1).

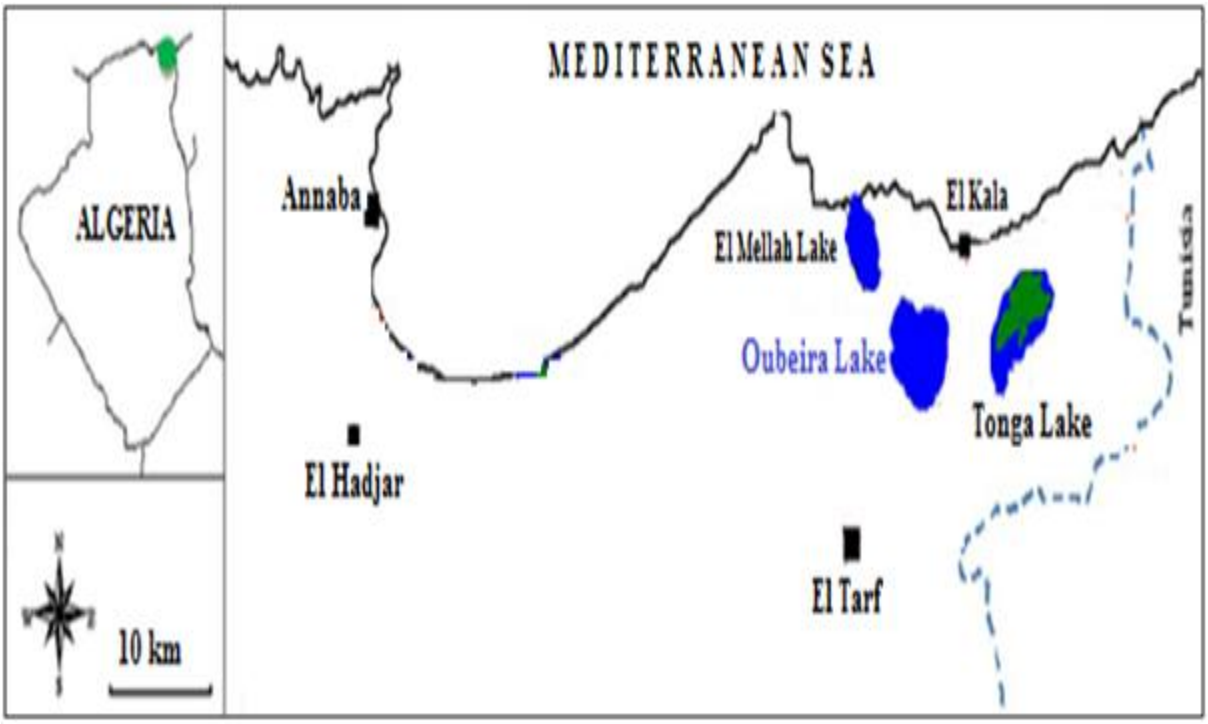

Fig. 1. Oubeïra Lake, in northeastern Algeria.

It is a designated wilderness area (registered with the Ramsar Convention) within the National Park of El Kala which has the unique distinction of being the most important wetland complex of the Maghreb area (Boumezbeur, 2003).

Capture and treatment of the eels

Sampling was carried out monthly (30 fish on each occasion) between November 2010 and April 2012. Eels were captured and brought back alive to the laboratory on ice and then weighed (total mass, Wt, to the nearest 0.1 g) and measured (total length, Lt, in mm). The horizontal and vertical diameters of the eyes and the length of the pectoral fin were measured to deduce the degree of silvering index using the reproductive capacity of the European eel (EELREP, 2005).Age of fish was estimated by otolithometry (Panfili*et al.,* 2012).

Environmental parameters (temperature, pH, Conductivity, dissolved oxygen and suspended solids) were measured monthly *in situ* using routine techniques. The parasites in each organ were removed and counted upon dissection. Species parasite identification was performed using a stereoscopic microscope.

The classical epidemiological parameters (e.g. P: prevalence, I: mean intensity, and A: abundance) were calculated following Bush *et al.* (1997).

Statistical analyses

Principal component analysis (PCA) was used as a descriptive and exploratory method aiming to characterize, in a multivariate way, changes through time the structuring and highlighting the contribution of environmental parameters on parasite abundance.The statistical analyses were carried out with the STATISTICA 8.0 Software.

Results

Epidemiological trends

Table 1 shows the epidemiological results of European eels captured in Oubeïra Lake. We found parasite richness comprised 6 species: 2 Crustacea (*Ergasilusgibbus*; *Argulusfolliaceus*), 1 Monogenea (*Pseudodactylogyrus* sp.), 2 Nematoda (*Hysterothylacium* sp., *Anguillicoloïdescrassus*) and 1 Cestoda (*Bothriocephalusclaviceps*).The most abundant parasite species for the whole sample was *E. gibbus* (11.73±11.07), followed by *Anguilicoloïdescrassus* and *Hysterothylacium* sp. (3.74±2.04 and 1.40±1.34 respectively).

Table 1. Epidemiological parameters of the parasite species.

Class	Parasites	P(%) ±SD	I ±SD	A ±SD
Crustacea	*Ergasilusgibbus*	83.40±14.9	16.15±10.46	13.76±11.07
	Argulusfolliaceus	15.89±22.57	2.41±4.5	1.09±3.24
Monogenea	*Pseudodactylogyrus*sp.	14.49±27.29	2.36±3.91	0.45±0.95
Nematoda	*Anguilicoloïdescrassus*	50.44±13.44	7.04±3.18	3.74±2.04
	*Hysterothylacium*sp.	53.56±23.75	2.28±1.13	1.40±1.34
Cestoda	*Bothriocephalusclaviceps*	24.22±19.62	1.17±0.42	0.31±0.26

P=prevalence, I=intensity, A=abundance, SD=standard deviation.

The EELREP Silvering index revealed that 17 fish had not undergone sexual differentiation, only 2 individuals were silvered males while 431 were females, of which more than half were silvered (238); the latter were the most infested group (5613 parasites) (Fig. 2).

Biological characteristics and parasite community of the European eel

Of the 450 specimens captured during the study period; fish sizes, weights and ages were ranged from 300-974 mm, 45-1330 g and 19-79 months respectively.

There is no correlation between biometric parameters and parasitism and parasites do not correspond with age and length groups (Table2).

Table 2. Correlation matrix (*E.=Ergasilusgibbus; A.=Argulusfolliaceus; P.=Pseudodactylogyrus*sp.; *An.=Anguilicoloïdescrassus; H.=Hysterothylacium*sp.; *B.=Bothriocephalusclaviceps*)

	E.	*A.*	*P.*	*An.*	*H.*	*B.*	Length	Weight	Age
E.	1,0	-0,03	0,11	-0,02	0,15	0,10	-0,03	0,00	-0,12
A.		1,00	0,23	0,01	0,02	0,04	0,00	0,00	0,08
P.			1,00	-0,03	-0,13	0,12	-0,12	-0,11	-0,14
An.				1,00	0,04	0,11	0,19	0,19	0,18
H.					1,00	-0,07	0,19	0,22	0,13
B.						1,00	0,03	0,00	-0,01
Length(mm)							1,00	0,96	0,79
Weight(g)								1,00	0,77
Age(month)									1,00

Differences in prevalence between each cycle sampled at Oubeïra Lake

To compare the same months of 2 successive years, we chose 2 identical cycles (from November, 2010 to April, 2011 and from November, 2011 to April, 2012). Both nematodes andcrustacean *E. gibbus*prevalences and their variability were very similar between both sampling periods. In contrast; cestode, monogenean andbranchiurashowed a difference in prevalence across the years (Table 3).

Statistical analyses

The use of principal component analysis (PCA) as a preliminary and exploratory descriptive technique was used explores relationships between environmental variables and parasite infestation during the sampling period in Oubeïra Lake. Eleven variables were measured: *Ergasilusgibbus*, *Argulusfolliaceus*, *Pseudodactylogyrus* sp., *Hysterothylacium* sp., *Anguillicoloïdescrassus* and *Bothriocephalusclaviceps* abundances, water temperature, pH, Dissolved Oxygen, conductivity and suspended solids.

Table 3. Differences in prevalence between each cycle sampled (ns,p>0.05; *,p<0,1; **,p<0,01).

Cycle 1	*E.*	*A.*	*P.*	*An.*	*H.*	*B.*
Cycle 2						
E.	ns					
A.		*				
P.			*			
An.				ns		
H.					ns	
B.						**

The two first main components (plan 1-2, Fig. 3) of the PCA based on the 6 parasite abundances variables accounted for 62.82% of the variation (inter-months variability). Different environmental parameters were used as supplementary variables.

Factor 1 explains 41.42% of the total variability; it is positively correlated with *Bothriocephalusclaviceps* (r = 0.87; cos² = 0.75), *Anguillicoloïdescrassus* (r = 0.77; cos² = 0.6) and *Pseudodactylogyrus* sp. (r = 0.76; cos² = 0.58) abundances and pH (r = 0.44; cos² = 0.2) but negatively correlated with *Argulusfolliaceus* (r = - 0.54; cos² = 0.3). This factor shows the difference between the months of the 1st cycle (November, 2010; December, 2010; January, 2011; and February, 2011) and months of the 2nd cycle (December, 2011; February, 2012; March, 2012 and April, 2012).

Factor 2, which explains 21.40% of the total variability, is positively correlated with *Ergasilusgibbus* and *Hysterothylacium* sp. variables (r=0.76; cos^2= 0.66 and r=0.77; cos^2= 0.5 respectively).

Discussion

This paper first describes the macroparasite community characteristics of a European eel population living in Oubeïra Lake and then examines how ecological traits of individual parasites and their historical events have evolved. How much of this variation is explained by selective pressures from the host or the physical environment is discussed.

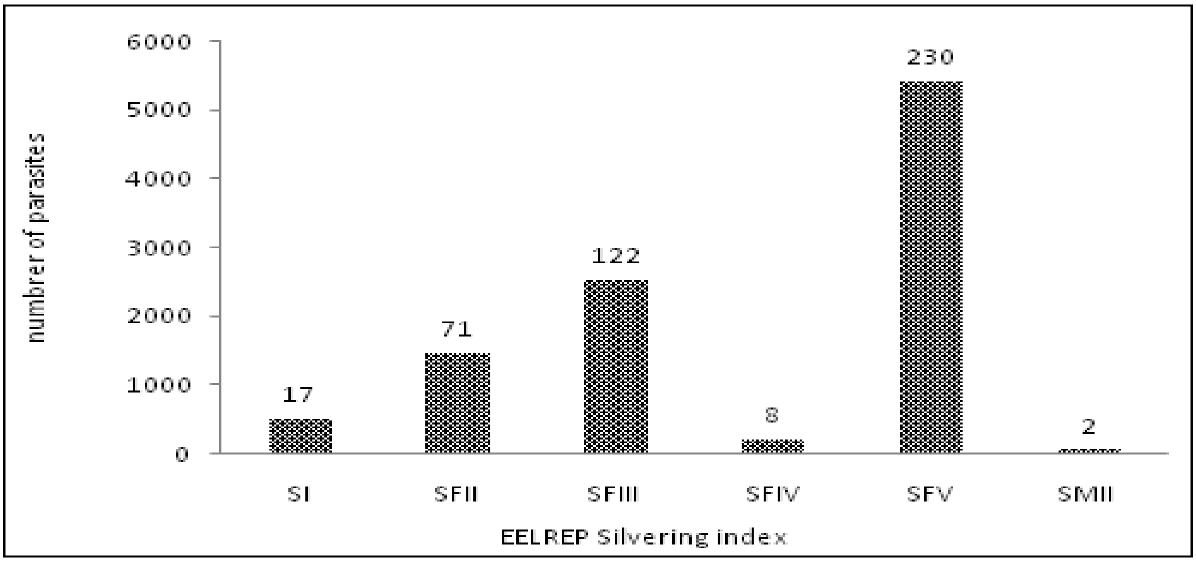

Fig. 2. Parasites abundance across EELREP Silvering index scores for eel captured in Oubeïra Lake.

Epidemiological trends

In terms of parasite richness, there were only six species of parasites found in the entire fish sample, this number is close to that reported by Filippi (2013) in Corsica (7 species) and both species scores are low in comparison with parasite infestation found on eels collected in France, Italy and Spain where 23, 10 and 11 species were recorded by Fazio *et al.* (2008), Kennedy *et al.* (1997) and Maillo *et al.* (2000) respectively. Kennedy (2007) described 55 species of helminthes parasites on European eels suggesting that parasite diversity in eels in north Mediterranean lagoons is high. The weak parasite diversity is probably explained by the extremely fast growth rate of the European eel of Oubeïra Lake and the good body condition (good immune status) (Tahri *et al.,* 2016).

The wide range of values in parasite abundance, prevalence and intensity highlights the predominance of some species in the parasite community; infestation by the crustacean *E.gibbus* was the most prevalent species on the eels captured in this study. In Spain Aguilar *et al.* (2005) found this species in *Anguillaanguilla* but infestation was also low in prevalence and intensity (1.55 %-3.5% of host specimens were affected with 1.29-7.4 parasites/gill). Nematodes infestation was higher and about half of the sampled fish sub-population was infested. Very similar findings have been reported for eels in the Mafrag estuary (P=46%, A=2.02 worms per fish) (Boudjadi*et al.,* 2009) and in fresh water bodies of the Park National of El Kala (e.g. lakes Tonga and Oubeïra) (Djebbari *et al.,* 2009), for which the authors report 4-5 times more infestation in these sites than in the Mellah lagoon.

B.claviceps is the third most prevalent taxon in this study. In the Adriatic lagoons, Di Cave *et al.* (2001) found 9.1% of eels infested while Caillot *et al.* (1999) record 20% in Corsica. Higher infestations are reported in Iberian Peninsula (SaraivaandEiras, 1996). This cestode was also found in fresh water eel populations of several continents (Borgsteede *et al.,* 1999).

The infestation by the copepod *Argulusfolliaceus* was relatively weak; this degree of infestation is supported by the results of RamdaneandTrilles (2007) and Boualleg*et al.* (2010) for the Algerian coastal fisheries, Benhassine *et al.* (1978); Benmansour (2001) for Tunisian coasts and Ternengo *et al.* (2005a) for France.

Pseudodactylogyrus sp. infestation was less frequent, it is an allochthonous species that is only found in a freshwater or oligohaline (very low salt content), it initial host is the Japanese eel (Koie, 1991). Very similar findings have been reported for Corsica (15%) (Caillot, 1999); however, Maillo *et al.* (2000) in Spain and Kennedy *et al.* (1997) in Italy found higher prevalence of specimens of this species (83.3% and 0-33.7% respectively), but the lowest values (1.25%) are recorded by Fazio *et al.* (2005) in Salses-Leucate lagoon (France).

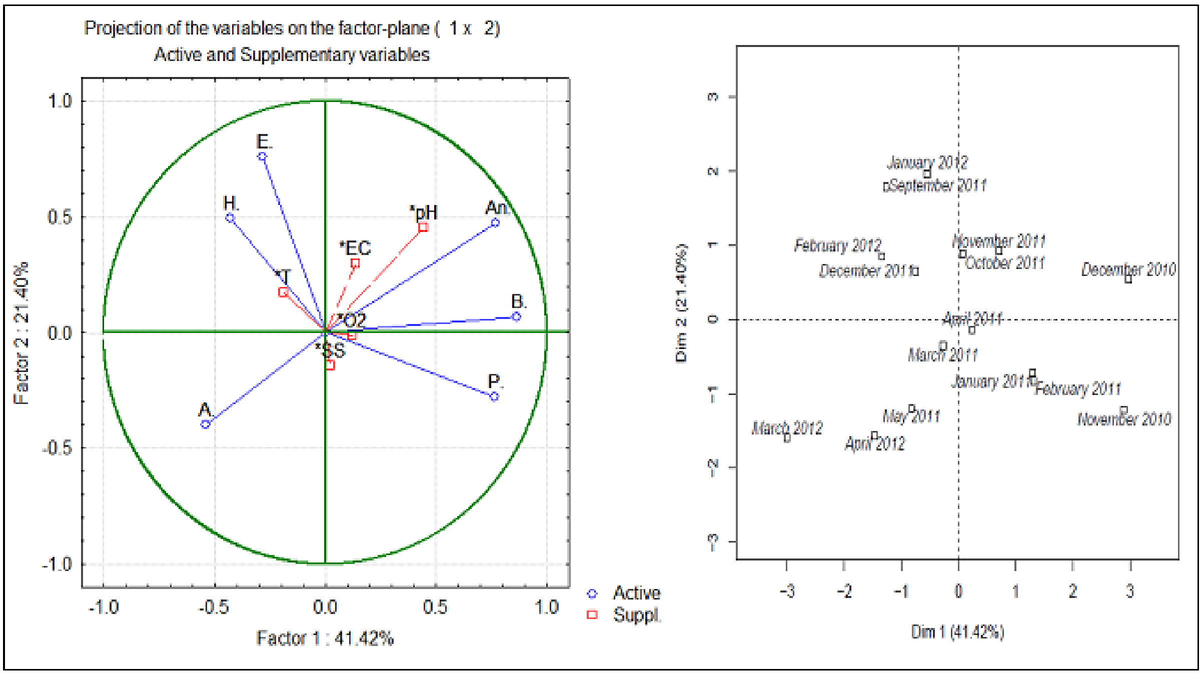

Fig. 3. Principal component analysis. Left: correlation circle of the 11 variables (Active variables: H: *Hysterothylacium,* An: *A. crassus,* E:*E. gibbus,* B: *B. claviceps,* A: *Argulusfolliaceus,* P: *Pseudodactylogyrus*sp. abundances; Supplementary variable: pH, EC: conductivity, T: temperature, O_2: dissolved oxygen, SS: suspended solids). Right: ordination diagram of each sampling date according to these 11 variables. Plan factorial (1, 2) factor 1: 41.42%, factor 2: 21.40 %.

This study indicates that silvering females are the most parasitized group, Pilosof *et al.* (2013) suggested that parasite abundance is related to host abundance, host individuals being more likely to be parasitized, and the probability of host-to-host transfer increases with host abundance (Krasnov *et al.,* 2002). Furthermore, some authors (Price, 1980) refer to a fundamental biogeographical law, that the big islands (therefore the big fish) have most resources (for example space) and therefore should be the most colonized. The absence of an effective immune response (Knopf, 2006; Nielsen and Esteve-Gassent, 2006) and longer exposure time should favor accumulation of parasites on hosts.

No link was observed between parasite abundance and the biotic characters of the host in this study. Hence, infestation appears to be independent of host specimen size. Comparisons of epidemiological values with other previously published data are however obfuscated by the differences in the sampling protocol, sample size and host size/age. Djebbari *et* *al.*(2009) show that the highest prevalence values are recorded in young specimens but, the highest values of mean intensity and abundance are noted in large eels. In contrast, Fazio *et al.* (2008) found significant negative relationships between *A. crassus* abundance and the length and age of eels.

Differences in prevalence between each cycle sampled

The temporal dynamics of functional roles of species based on the inter-year differences and parasite prevalence is discussed for the first time. Hence, we showed that the prevalence of half the species (monogenean, cestode and copepod) occurring in each annual cycle is clearly different. These results are supported by statistical analysis (PCA) that revealed a monthly difference in both cycle. Environmental stochasticity may explain some of the high interspecific temporal variation (Pilosof *et al.,* 2013). For example, unusually cold weather can delay the development of a subset of ecto-parasite species that are more sensitive to climatic fluctuations (Krasnov *et al.*, 2001). Climatic fluctuations have also been suggested to affect temporal variation in the structure of a mutualistic network (Alarcon *et al.,* 2008).

Link between parasitism and abiotic characters of the lake

The use of Principal Component Analysis indicated that *A. crassus*, *B. claviceps*and *Pseudodactylogyrus* sp. abundances are positively correlated with pH water. Similarly, a positive correlation between *A. crassus* and *Pseudodactylogyrus* sp. abundances was reported by Fazio *et al.* (2008), the most plausible explanation according to the authors is that *A. crassus* would disturb the swimming and preying behaviors of infected eels, which would enhance the encounter with the oncomiracidia of *Pseudodactylogyrus* sp. Concerning correlation of both parasites with *B. claviceps*, it may be random because the 3 specimens occupy different niches (gill, swimbladder and gut). Concerning the correlation with pH, it may be an artifact and not related to cause and effect, in addition pH covaries with other water quality variables including lake productivity that could promote infestation (cf. Lafferty and Kuris, 1999).

Conclusion

European eel living Oubeïra Lake, are infected by six metazoan parasite taxa, the half of them shows a difference in prevalence across the years. The nematode *A.crassus*, the cestode*B. claviceps* and the monogenean *Pseudodactylogyrus*sp. seem to be positively linked in space.

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