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Research Article

Anguillicolosis Infection and Pathological Status of the Swim Bladder Wetland Eels (Extreme North-East of Algeria)

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Abstract

Background: The parasite *Anguillicoloide scrassus* causes profound damage to the swim bladder of eels and may impair their spawning migration to the Sargasso Sea to complete its reproductive cycle. In this investigation, evaluated the current infection rate (by lumen worms of the swim bladders) and past infections (e.g., as evidenced by damage to the swim bladders) of the European eels that populates three water dam of Parc National of El Kala (Northern Africa). **Materials and Methods:** A seasonal rate was performed, by collecting parasites and measuring morphological parameters (length and weight of fish) from the three water dam: Tonga lake (96 eels of length ranged from 359 and 630 mm), Oubeira lake (135 eels of length ranged from 412 and 650 mm) and Mellah lagoon (147 eels of length ranged from 261 and 825 mm) of the Parc National of El Kala. After dissection, the classical epidemiological parameters and the SDI were calculated. For analysis of data STATISTICA 8.0 Software was used. **Results:** The results revealed a mean prevalence of 29, 67.16 and 4.26%, a mean intensity of infestation of 2.8, 7.46 and 2.89 per swim bladder, a mean abundance of 0.86, 4.94 and 0.21 per eel in Tonga, Oubeira and Mellah, respectively. The highest prevalence values are recorded in larger fish and all eels of the sampling area show pathological signs of infection in their swim bladder, however, it is the eels of the lagoon that are the least affected. **Conclusion:** The evaluation of the swim bladder degenerative index (SDI) remains an important tool to estimate the health state of the swim bladder and represent a meaningful measure in epidemiological studies of anguillicolosis.

Key words: Eel, swim bladder, anguillicolosis, *Anguillicoloide scrassus*, helminthiasis, North Africa

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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

The international collaborative investigation of the reproductive status of the European eel¹ has declared that in case of heavy swim bladder infection and/or damage; eels will never reach the spawning grounds and cannot contribute to recruitment. The infection of the swim bladder of the European eel *Anguilla anguilla* by the invasive nematode *Anguillicoloides crassus* Kuwahara, Niimi et Itagaki, 1974 has possible negative effects on body condition, swimming capacity and survival²⁻⁴. Many authors reported that larvae cause inflammatory reactions⁵ and impaired functioning and spawning migration of the eels to Sargasso Sea^{2,6,7}. Moreover, it was also shown that *A. crassus* infection induces a series of physiological stress responses that overall leads to an increased metabolic rate⁸⁻¹⁰.

This nematode was introduced to Germany with the importation of infected Japanese eels *Anguilla japonica* from Taiwan in 1980 and has spread all over Europe and North Africa within 10 years, infecting most of the European eels¹¹. The presence of this worm in eels of the aquatic ecosystem of the North-East of Algeria was recorded for the first time in 1999¹². Studies of the European eel have been performed at the various hydro-systems in the extreme northeast of Algeria where *A. anguilla* is typically found¹³⁻¹⁸. These studies only focused on the inventory of the parasites in lakes, estuaries and lagoons, without consideration of the pathological aspect or the parasitic chronology of the fish. The first study on the status of the swim bladders of *A. anguilla* by assessment of their swim bladder degenerative index (SDI) was performed in European eels populating Lake Oubeira¹⁸. According to Lefebvre *et al.*¹⁹, the most severe stage of the infection depends on the health status of the swim bladder (e.g., anatomical deformations and physiological dysfunction resulting from the infestation), rather than on the number of parasites in this organ. Szekely *et al.*²⁰ noted that the degradations in the infected swim bladder tend to accumulate over time as a result of chronic infections; therefore the SDI encapsulates the combined effects of past and current infections.

The objective of the present study was to evaluate the current infection rate (by lumen worms) and past infections (e.g., as evidenced by damage to the swim bladders) of the European eels collected from Tonga and Oubeira freshwater lakes and from Mellah brackish water lagoon situated in the National Park of El Kala (extreme North-East of Algeria).

MATERIALS AND METHODS

Capture and treatment of the eels: Sampling was carried out seasonally between December, 2015 and May, 2017 (Table 1) from three localities (the Oubeira Lake, the Tonga Lake and the Mellah lagoon) situated in Parc National of El Kala (Algeria North-East); this area has the unique distinction of being the most important wetland complex of the Maghreb²¹ (Fig. 1).

Eels were captured and brought back alive to the laboratory on ice and then weighed (total mass, weight, to the nearest 0.1 g) and measured (total length (mm)). After dissection, the swim bladder of all eels was removed and macroscopically examined for the presence of *A. crassus* and the number of lumen worms was recorded. Finally, the classical epidemiological parameters (e.g., P: Prevalence, I: Mean intensity and A: Abundance) were calculated following Bush *et al.*²².

Swim bladder degenerative index (SDI): The assessment was based on gross pathology of excised swim bladders and was adapted from Lefebvre *et al.*²³. Three criteria were used which are: The thickness, the opacity and the pigmentation of the swim bladders (each one coded by 0, 1 or 2, increasing degradation). This index is ranged from 0-6: Value of 0 corresponds with an intact swim bladder, values from 1-3 correspond with a moderately damaged swim bladder, while values from 4-6 correspond with severely damaged swim bladders (at a value of 6, no lumen is left).

Statistical analyses: The non-parametric test of Kruskal-Wallis was used in this study and carried out with the STATISTICA 8.0 Software (StatSoft Inc.)²⁴.

Table 1: Morphological characteristics of the eels sampled

Sites	Sampling dates	N	Length (mm)	Weight (g)
Oubeira	Winter 2015-2016	72	569.4±53.1	345.30±93.62
	Spring 2016	63	548.9±71.73	299.10±99.5
Tonga	Autumn 2016	51	465.1±70.6	167.80±70.51
	Winter 2016-2017	45	533.8±83.3	243.43±85.13
Mellah	Autumn 2016	38	427.1±60.3	141.89±61.02
	Winter 2016-2017	60	495.7±99.3	210.68±264.61
	Spring 2017	49	440.9±100.9	157.06±238.74

Data are presented as Mean±Standard Deviation

RESULTS

Captured eels: For the 378 eels captured during the study period, the fish sizes ranged from 251-113, 359-630 and 391-693 mm from Mellah, Tonga and Oubeira respectively.

The most important sizes were 500-600 mm for both lakes and 400-500 mm for the lagoon (Fig. 2).

Evolutionary dynamics of *A. crassus*: The seasonal infestation rates varied from 59.72-74.6% in Oubeira, from 23-35% in Tonga and from 0-6.67% in Mellah; besides, it is in this last that

we recorded the lowest rates. Concerning the intensity of infestation and the abundance of *A. crassus*, the highest values were recorded in winter in all the sites (Table 2).

In Oubeira, the infestation rates increased with eel size; however, they remain less than 33.33% in the other sites. The highest intensity and abundance were observed in eel ranged between 500-600 mm in Oubeira and between 400-500 mm in Tonga and Mellah (Table 3).

In Oubeira, very few eels had an intact swim bladder (in which 21 worms were recorded) and 67.16% are severely damaged; the opposite situation also occurred in Mellah; i.e.,

Table 2: Epidemiological parameters of *A. crassus* of the eels sampled as function as season

Sites	Sampling dates	N	Prevalence (%)	Intensity	Abundance
Oubeira	Winter 2015-2016	72	59.72	8.79	5.25
	Spring 2016	63	74.6	6.21	4.63
Tonga	Autumn 2016	51	23	2.16	0.5
	Winter 2016-2017	45	35	3.43	1.22
Mellah	Autumn 2016	38	0	0	0
	Winter 2016-2017	60	6.67	5	0.42
	Spring 2017	49	6.12	3.66	0.22

Table 3: Epidemiological parameters of *A. crassus* as function as length classes of the eels sampled

Length classes (mm)	Oubeira			Tonga			Mellah		
	P (%)	I	A	P (%)	I	A	P (%)	I	A
200-300	0	0	0	0	0	0	0	0	0
300-400	25	1.5	0.75	12.5	0.63	0.16	2.38	0.33	0.02
400-500	47.22	6.25	2.83	23.5	4.38	0.8	13.73	4.67	0.14
500-600	66.69	10.49	6.58	30	2.71	0.94	3.03	1.5	0.14
600-700	76.67	5.05	3.98	12.5	1	0.25	33.33	2.33	1.17
700-800	0	0	0	0	0	0	0	0	0

P: Prevalence, I: Intensity, A: Abundance

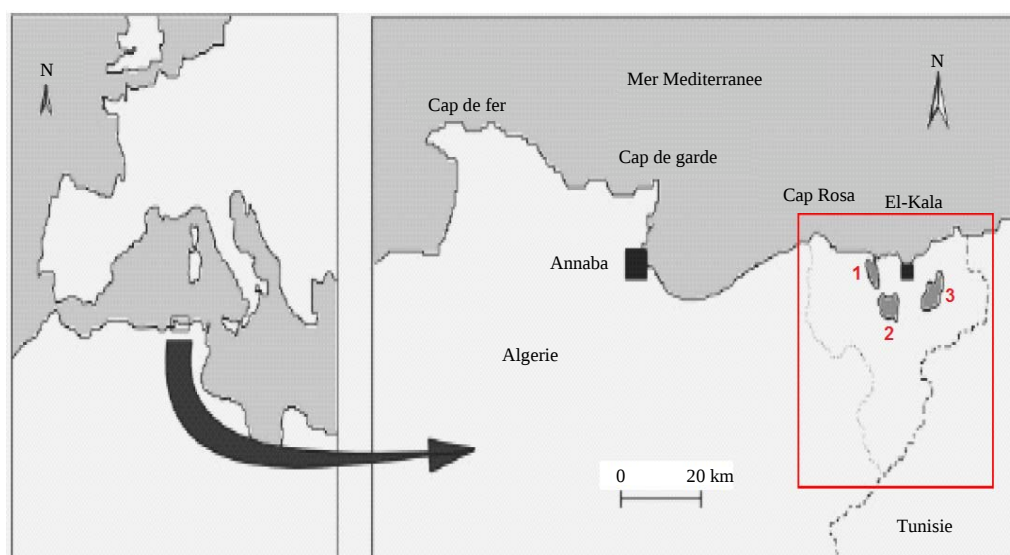


Fig. 1: Sampling sites in Northeastern Algeria

1: Mellah lagoon, 2: Oubeira lake and 3: Tonga lake

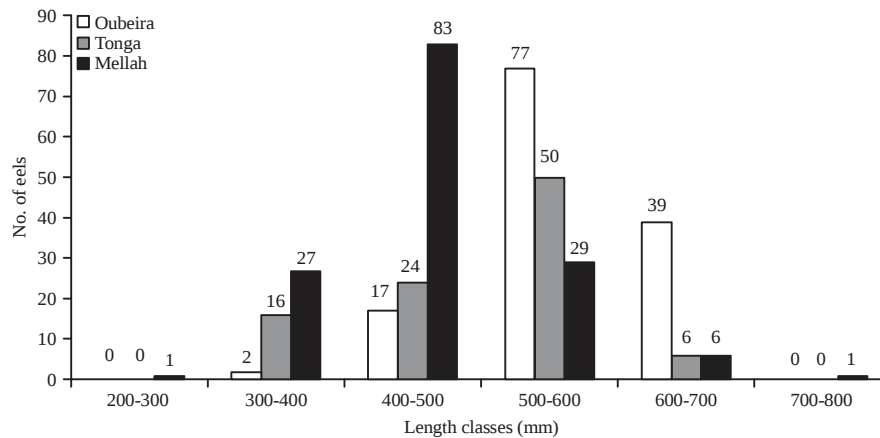


Fig. 2: Size distribution ranges for eels captured

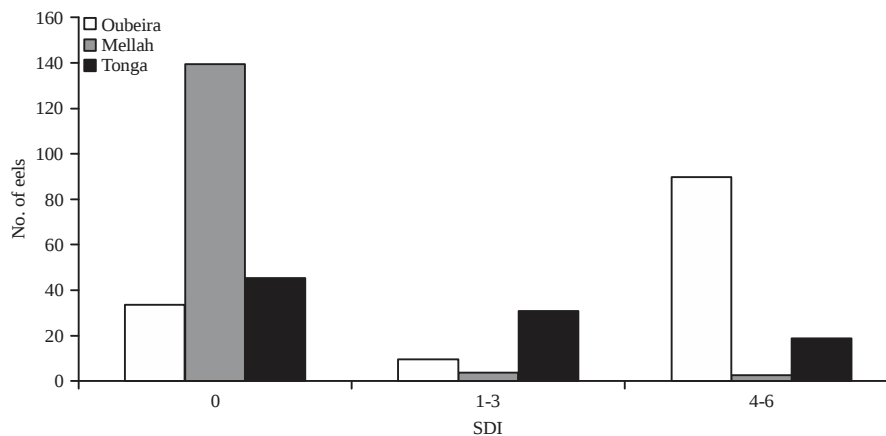


Fig. 3: Distribution of swim bladder degenerative index (SDI)

95.24% of intact swim bladder against 2.04% of severely damaged one. In Tonga, almost the half of the swim bladder (46) was intact; the others were considered as damaged to severely damaged (Fig. 3).

The mean abundance of *A. crassus* varied significantly as a function of the values of the swim bladder degenerative index (SDI) in both lakes (Kruskal-Wallis test H Tonga (6; 96) = 30.18; $p < 0.001$, Kruskal-Wallis test H Oubeira (6; 135) = 61.56; $p < 0.001$) but there was not difference in the lagoon (Kruskal-Wallis test H Mellah (4; 147) = 6.75; $p > 0.05$) (Fig. 4).

DISCUSSION

Eel samples collected from Oubeira, Tonga and Mellah revealed respectively a mean prevalence of 67.16, 29 and 4.26%, a mean intensity of infestation of 7.5, 2.8 and 2.88 per swim bladder and a mean abundance of 4.94, 0.86 and 0.21 per host. In Tonga, Nabil *et al.*¹⁴ denoted infestation rates

of 68%. In Oubeira, the epidemiological parameters reported by Tahri *et al.*¹⁸, were close to those revealed by our investigation ($P = 50.44\%$, $I = 7.04 \pm 3.18$, $A = 3.74 \pm 2.04$). In the fresh water bodies of the Parc National of El Kala (e.g., lakes Tonga and Oubeira), for which the researchers reports that there are 4-5 times more worms in these sites than in the Mellah lagoon¹⁶. Lefebvre *et al.*²⁵ have confirmed that high salinities limit, if not preclude, high infestation rates by *A. crassus*. High salinities can create unsuitable or non-optimal eco-physiological conditions for the parasite to complete its life cycle; indeed, it may narrow the range of available/compatible hosts (whether intermediate or paratenic) and the presence of vector hosts in the medium is of primary importance, especially in the context of parasitic colonization^{26,27}.

Lefebvre *et al.*²⁵ in their analysis, found a clear negative correlation between salinity and *A. crassus* prevalence values across all sites but they also showed that infection rates are influenced by latitude. Thus, low prevalence's are more often

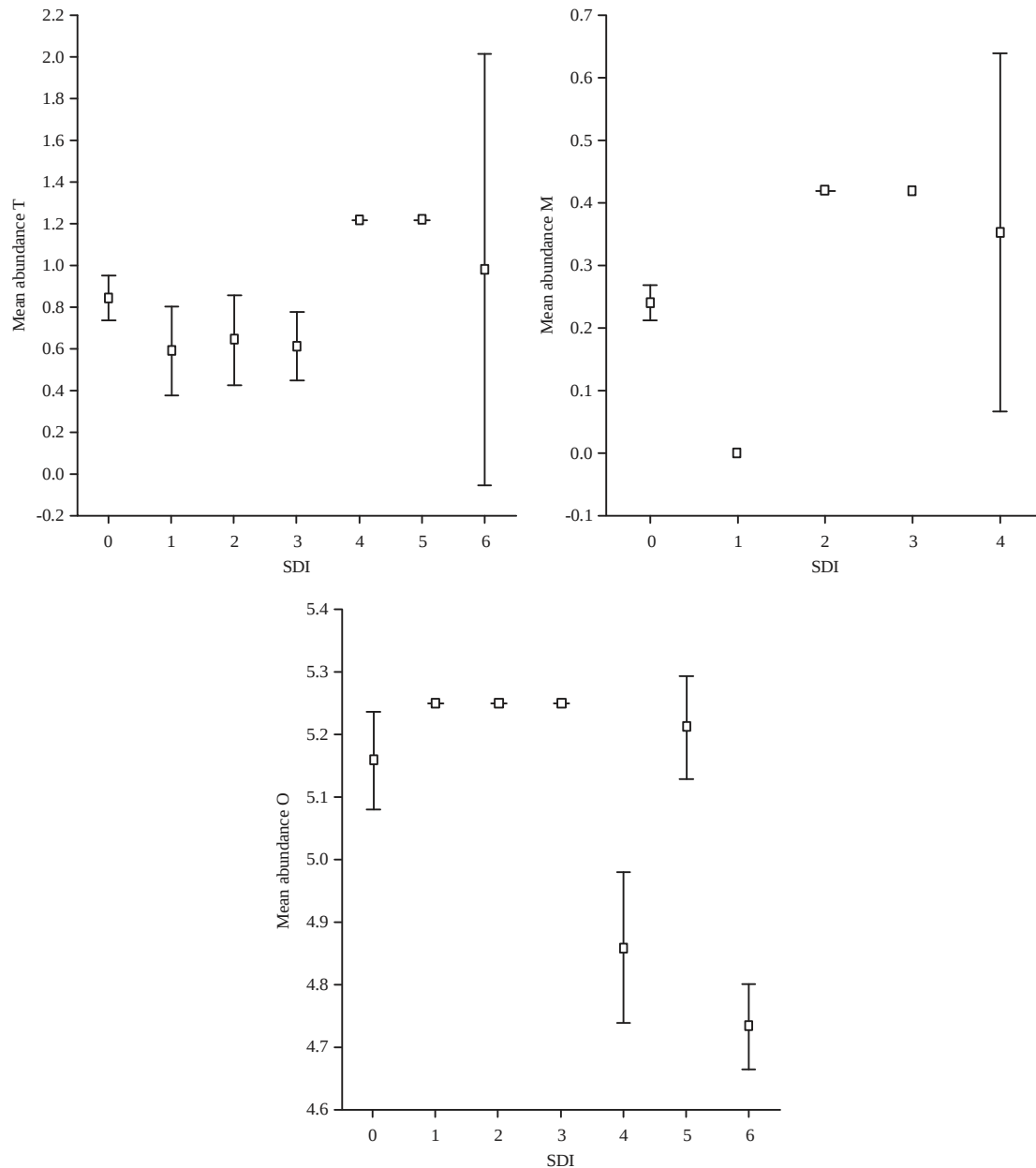


Fig. 4: Mean abundance (±SD) of *Anguillicoloides crassus* by SDI

found associated with high latitudes. However, this trend observed at a global scale does not preclude the colonization of the Northern most range of the eel hosts, as recently documented by the occurrence of *A. crassus* above 60° N in Scandinavian countries, for *A. anguilla*²⁸ and in Canada, for *A. rostrata*²⁹.

In light of this, scientists have proposed using salinity as a natural mean for disease control. Such a measure has in fact already received backing from many ichthyoparasitologists and eel specialists³⁰⁻³².

In all sites, the lowest seasonal infestation rate is recorded in autumn and winter. The monthly epidemiological variation may be related to the thermal changes; indeed, the lower winter temperature (10-12°C) in the sites studied would prevent the progress of the life cycle of this nematode. In the Sebou estuary in Morocco, the infestation exhibits seasonal variations, fluctuating from 12.79-55.36%. The prevalence and abundance are relatively high and they have been positively correlated with the length and weight of the fish³³. In the Bizerte and Ghar El Melh lagoons of Tunisia, where the salinity

approaches that of seawater (33-34‰), the nematode is present for just one to three months of the year, while also exhibiting low epidemiological values³⁴. Lastly, a 2 years survey of four habitats in the Camargue area (Rhône delta, South of France) revealed negative relationships between parasitic parameters (e.g., prevalence, mean intensity and abundance) and salinity values of (i.e., a prevalence of 52% in brackish waters to 77% in fresh waters)¹⁹.

The study of the parasitism evolution from a consideration of the size of the host shows that the highest prevalence values are recorded in large eels. The value increases with the increase of the size of the host. The same result has been reported by Lefebvre *et al.*²³, this finding is may be due to the longer exposure time of parasites in hosts. Other studies showed a negative relation^{34,35} between parasite abundance and the size of eels.

In North Africa, studies have been limited to the determination of conventional parasitic parameters and no studies have been carried out regarding the Swim bladder Degenerative Index. Yetas of 2005, EELREP has recommended reliance on the SDI, as described by Lefebvre *et al.*²³, to obtain an indication of prior swim bladder infestation, as well as to gain information in regard to their functional status.

Nearly all eels of the sampling area show pathological signs of infection in their swim bladder; however, it is the eels of Oubeira that are the most affected follow directly by those of Tonga, more than 95.24% of those of the lagoon eels are intact. A Tunisian study³⁶ has reported an average swim bladder degenerative index of 0.28 and that 6.09% of the eels exhibited signs of previous infection, while 9.75% appeared to have either prior or current infections. More extensive damage has been observed in French lagoons, where 92% of the eels exhibited pathological signs of infection and the severely damaged swim bladders harbored very few live nematodes¹⁹. Lastly, *A. crassus* infection has been determined to be widespread in Portugal's brackish water systems, where 67% of the swim bladders were found to be damaged (SDI = 1.31 ± 1.23)³⁷.

CONCLUSION

The results revealed a mean prevalence of 29, 67.16 and 4.26%, a mean intensity of infestation of 2.8, 7.46 and 2.89 per swim bladder, a mean abundance of 0.86, 4.94 and 0.21 per eel in Tonga, Oubeira and Mellah respectively. In addition, the general trend in this study was of increasing damage as the host size rose and the majority of infested eels are found in fresh water.

SIGNIFICANCE STATEMENTS

This study assess the health of the swim bladders of the European eels (living in northeastern Algeria's wetland), by the evaluation of an index that is based on 3 criteria: the thickness, the opacity and the pigmentation of the swim bladders; while parasitism traditionally was used to address the rate of infestation as well as classical counting of the parasites without considering the functional status of the swim bladders. This study will help the researcher to easily assess the health state of the eel swim bladder (that it is crucial to the survival of this fish), that many researchers were not able to explore.

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